Maximizing U.S. Interests in Science and Technology Relations with Japan

Committee on Japan Framework Statement
and
Report of the Competitiveness Task Force

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National Research Council

20011101 061

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Committee on Japan Framework Statement and Report of the Competitiveness Task Force

Committee on Japan
Office of Japan Affairs
Office of International Affairs
National Research Council

National Academy Press
Washington, D.C. 1997

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This project was made possible with funding support from the U.S. Department of Commerce, U.S. Department of Energy (award no. DE-FG02-93ER30209), U.S. Department of State, U.S. Department of Defense, and the National Science Foundation.

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International Standard Book Number 0-309-05884-8

Additional copies of this report are available from National Academy Press, 2101 Constitution Avenue, N.W., Lockbox 285, Washington, D.C. 20055; (800) 624-6242 or (202) 334-3313 (in the Washington area); Internet, http://www.nap.edu.

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Since 1985 the National Academy of Sciences and the National Academy of Engineering have engaged in a series of high-level discussions on advanced technology and the international environment with a counterpart group of Japanese scientists, engineers, and industrialists. One outcome of these discussions was a deepened understanding of the importance of promoting a more balanced two-way flow of people and information between the research and development systems in the two countries. Another result was a broader recognition of the need to address the science and technology policy issues increasingly central to a changing U.S.-Japan relationship. In 1987 the National Research Council, the operating arm of both the National Academy of Sciences and the National Academy of Engineering, authorized first-year funding for the Office of Japan Affairs (OJA). This program element of the Office of International Affairs was formally established in the spring of 1988.

The primary objectives of OJA are to provide a resource to the Academy complex and the broader U.S. science and engineering communities for information on Japanese science and technology, to promote better working relationships between the technical communities in the two countries by developing a process of deepened dialogue on issues of mutual concern, and to address policy issues surrounding a changing U.S.-Japan science and technology relationship.

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A Framework for Maximizing U.S. Interests in Science and Technology Relations with Japan

This report is the final product of the Committee on Japan's (COJ) overview study on Maximizing U.S. Interests in Science and Technology Relations with Japan.[1] The study examines the major U.S. interests at stake in science and technology relations, identifies long-term strategic priorities, and recommends specific actions for U.S. government, industry, and research institutions to advance U.S. interests. This framework statement is based on the findings and recommendations of the Defense Task Force (DTF), which released its final report in 1995, and Competitiveness Task Force (CTF), which completed its work in July 1997.[2] The study was requested in the Defense Authorization Act of 1992-1993.[3]

CONTEXT AND MOTIVATION FOR THE STUDY

When this study was requested and conceived, Japan was enjoying considerable success in high technology. Based largely on superior performance in manufacturing quality, marketing, and product development, Japanese companies gained global market share throughout the 1980s in manufacturing and technology-intensive industries such as automobiles, consumer and industrial electronics, advanced machinery, and important areas of advanced materials. Japanese industries established dominant positions in critical component and equipment areas such as dynamic random access memories, liquid crystal displays, and photolithography.

Leveraging this strong competitive position, Japanese firms moved aggressively to increase their ties to U.S. science and technology through investments in high-technology companies and support for U.S. university research. In fields where Japan was behind, a range of targeted government-industry programs had been launched to close the gap. Even in military and aerospace technologies, areas where Japan had been considered relatively weak, Japanese industry had diffused know-how acquired through military programs to gain important footholds in certain high-technology commercial sectors such as aircraft and space. The FS-X fighter co-development project symbolized Japan's ambition to ascend to the world's top tier in all key technology areas.

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[1] The study was supported by the National Institute of Standards and Technology of the Department of Commerce, the Department of Defense, the Department of Energy, the Department of State, and the National Science Foundation. In undertaking the study, the two task forces and the Committee on Japan also drew on other work from recent years supported by the Rockefeller Brothers Fund and the United States-Japan Foundation. See Appendix B for complete Committee on Japan bibliography.

[2] The framework outline was developed at a Committee on Japan meeting on June 3, 1997. Drafts were shared with members of the Committee on Japan, Competitiveness Task Force, and Defense Task Force, and their input was incorporated. The background information supporting the framework statement is contained in the task force reports.

[3] "Beyond these specific administrative improvements, the committee is interested in promoting a comprehensive assessment of scientific and technological relations between the United States and Japan. Therefore, the committee directs the Secretary of Defense to commission an independent study of this subject by the National Academy of Sciences. The study should analyze the strengths and weaknesses in Japanese science and technology and present a framework for pursuing U.S. interests through scientific and technological relations with Japan in the future." Committee on Armed Services, United States Senate, *National Defense Authorization Act for Fiscal Years 1992 and 1993* (Washington, D.C.: U.S. Government Printing Office, 1991), pp. 173-174.

Japan's science and technology successes and momentum, combined with the difficulties being experienced by many U.S. companies and industries at that time, led to increased focus on the U.S.-Japan science and technology relationship. A number of concerns and questions were raised. Why were Japanese companies apparently better positioned to capitalize on U.S. innovations than were U.S. firms? Would Japanese dominance of some critical component and equipment areas leave U.S. consumers and producers vulnerable to anticompetitive practices, and impair the ability of the United States to incorporate leading edge commercial technologies in weapons systems? Was it appropriate for Japanese firms to enjoy access to a U.S. university research base built through years of U.S. government investment, while providing only incremental funding? Did Japan's relative emphasis on targeted research in proprietary settings over more fundamental work in open settings constitute "free-riding" on the world's fundamental research base? Would rising Japanese investments in U.S. manufacturing and high technology help to sustain U.S. capability to innovate? Would increased U.S.-Japan trade friction centered on high technology lead to a split in the security alliance? Why had most U.S. efforts to achieve greater reciprocity produced disappointing results, at times appearing to place even greater strains on the U.S.-Japan relationship?

Over the time that the study has been conducted, some elements of this context have shifted dramatically. On the national security side, the United States and Japan have mostly reaffirmed existing arrangements and taken initial steps to reorient the security alliance to fit the post-Cold War environment. On the economic side, the U.S. economy and U.S.-based companies appear to be very strong today, while Japanese advantages have diminished and in some cases dissipated. In particular, U.S. strengths in innovation and technology commercialization have reasserted themselves. The emergence of new high-technology competitors based in Asia is affecting U.S. and Japanese strategies, prompting a shift in focus from bilateral to multilateral relationships.

At the same time, important aspects of the U.S.-Japan science and technology relationship, including many traditional asymmetries in exchange and cooperation, have not fundamentally changed.

This framework statement seeks to integrate the findings and recommendations of the two task forces, outline the long-term U.S. interests that are at stake in the science and technology relationship with Japan, and highlight the key priorities that the U.S. public and private sectors should pursue in the future.

LONG-TERM U.S. INTERESTS AT STAKE

Future U.S. economic performance and security depend to a considerable extent on maintaining and enhancing U.S. capabilities to generate and utilize innovation in developing and producing competitive goods and services for the global market. Science and technology relations with Japan can affect these capabilities in a number of ways.

In the national security area, cooperation in defense production, often involving transfer of U.S. technology to Japan, has long been an important part of the alliance. This cooperation has facilitated increased Japanese defense capabilities within the alliance and generated revenue for U.S. companies that could be reinvested in next-generation technologies. The alliance itself has advanced long-standing U.S. security interests in Asia, such as preventing the rise of a hegemonic power, ensuring the freedom of sea lanes in the region, and expanding commerce and trade. This cooperation has also delivered considerable benefits to Japan, in the form of enhanced manufacturing capabilities, and a business and technological base in aircraft and related components industries needed to enter commercial markets.

Although the U.S.-Japan security alliance continues to advance fundamental U.S. security interests, the overall security environment and the relative capabilities of the partners have changed. Patterns of cooperation should change as well. Cooperation featuring primarily one-way transfers of defense technology from the United States to Japan can no longer be justified by U.S. security interests. Rather, expanded, reciprocal cooperation with Japan in defense and dual-use technology could potentially advance U.S. interests in a number of ways. For example, U.S. systems would benefit from incorporation of leading-edge Japanese commercial technologies. The United States and Japan could also develop, manufacture, and upgrade common systems at lower cost. Although an equal balance in defense technology flow is not a realistic expectation in the foreseeable future, due to wide discrepancies in capabilities, more reciprocal cooperation in these areas could become a positive focus of U.S.-Japan interchange, enhancing the overall security alliance.

In the civilian technology arena it was agreed that creating and maintaining high-wage employment over the long term should be the key U.S. economic performance goal. The experience of recent years has made it abundantly clear that U.S. capability to generate and utilize innovation is a critical element in creating and maintaining good jobs for U.S. citizens and enhancing our standard of living.

The U.S.-Japan science and technology relationship can have an impact on U.S. capability to innovate in several areas. For example, it is increasingly important for U.S.-generated innovations to gain access to global markets, particularly early in the innovation cycle. Global market participation generates income for future technology investments and provides opportunities to learn from a global base of sophisticated customers and suppliers. Japan plays a key role as one of the largest, most advanced markets for many high technology products. It is just as important for U.S. interests that products based on U.S. innovations access Japan's market as it is to Japan that innovative Japanese products access the U.S. market.

In addition, competition and investment from Japanese companies can contribute to maintaining U.S. capabilities. Many U.S.-based companies have improved their performance in response to challenges from Japan-based competitors. Through investment in U.S. research and development (R&D) and manufacturing, Japan-based companies have begun to contribute to overall U.S. capability to innovate.

Further, Japan is increasing government R&D investments aimed at strengthening its own fundamental research base and will move ahead of the United States in absolute non-defense government R&D spending early in the next decade if current trends continue. U.S. entities and the U.S. innovation infrastructure may derive increasing benefits from monitoring, tapping, and leveraging Japan's expanding capability; being second is not a familiar position for the United States. This does not, of course, diminish the importance of maintaining U.S. R&D investments and infrastructure.

Finally, some of the positive and negative lessons of the U.S. experience in competing and cooperating with Japan can be utilized in relationships with emerging techno-industrial powers, particularly in Asia. A number of the issues arising in relations with some Asian countries are similar to those encountered in the relationship with Japan, such as difficulties in protecting intellectual property, and strong public-private partnerships aimed at maximizing inward technology flow.

The potential for negative impact on U.S. interests from possible anticompetitive Japanese business practices, withholding technology, U.S. dependence on Japanese dual-use components and equipment for military systems, and Japanese ownership of U.S. high-technology assets, appears to have diminished in recent years. This is due to a combination of factors, including the resurgence of some U.S. companies and the entry of new competitors. As technological capability becomes more global and the international division of labor in high-technology products becomes more complex, it is very possible that potentially harmful concentrations of

high-technology production and capability will emerge in Japan or in other countries in the future. In order to minimize the risks of negative impacts on U.S. interests, it will be necessary to continue efforts within the World Trade Organization and other bodies to promote open markets and transparent competition policies on a global basis.

The findings and conclusions of the two task force reports highlight several key priorities, specific action items, and issues for possible future study.

MARKET PARTICIPATION SPURS INNOVATION

Expanding sales of innovative U.S. products and services is a vital long-term economic and national security interest. As pointed out above, global sales provide revenues for future technology investments, as well as opportunities to learn from sophisticated customers and suppliers. In the long term, U.S. economic and security interests do not conflict but rather complement one another. America's innovative infrastructure and human resources underlie future economic performance and military capabilities. Indeed, the economic foundations of national security have been more widely appreciated in recent years and have long been appreciated in Japan.

Japanese government and industry have traditionally aimed to maximize inward technology transfer while limiting market participation by foreign-based firms. Substantial progress toward more open Japanese markets has been made in areas such as software, semiconductors, and personal computers. However, there is evidence that a number of Japanese manufacturing and high-technology markets, such as telecommunications, auto components, and areas of production equipment, remain difficult to access. Japan remains by far the largest single-country market outside the United States for high-technology products. Japan-based companies, as a group, will remain the most important competitors and partners for U.S.-based companies in high-technology industries. Despite the current difficulties being experienced by Japanese companies and the Japanese economy, full participation in the Japanese market remains an urgent priority.

The United States would not be the only beneficiary from accelerated progress in this area. Since dynamic markets help to spur innovation, particularly at the frontiers of technology, high barriers to domestic and foreign-based entrants have contributed to recent difficulties in innovation experienced by some Japanese companies and industries.

Although the emerging techno-industrial powers of Asia are employing a variety of approaches to building technological capability and high-technology industries, some of the positive and negative lessons from the historical experience with Japan are applicable. In particular, the ability to protect intellectual property is a key factor in accessing markets, and U.S. innovators have experienced difficulties in Japan and other Asian countries. The long delay experienced by Texas Instruments in receiving patents for its basic semiconductor technologies in Japan is a well-known example.

The United States can take a number of steps to improve opportunities for market participation in Japan and elsewhere in Asia. Intellectual property protection should be a special focus. The U.S. Trade Representative's Office and the U.S. Patent and Trademark Office should develop a program to monitor patent applications by U.S. citizens in Japan and perhaps other countries that cover major scientific and technological advances.[4] This effort would help ensure that critical patents receive timely and effective international protection.

On the multilateral trade front, effective implementation of the Uruguay Round will advance U.S. interests considerably. In future multilateral negotiations, the United States should focus on

[4] In this context, the term "U.S. citizen" is intended to cover U.S.-generated innovations, including patents filed by companies, universities, and other organizations, as well as individual inventors.

areas where barriers to participation in the Japanese market continue to arise: direct investment and competition policy (antitrust). The United States should also explore expanded policy cooperation and coordination with Japan in trade policy areas where we share common interests, such as ensuring minimum standards for intellectual property protection.

The private sector has an important role to play as well. U.S. industry and industry associations should redouble their efforts to expand access to the Japanese market and Japanese technology and seek a greater role in policy processes and debates, both in Japan and the United States. Participation in standards-setting, advisory committees, and monitoring implementation of official agreements are examples of areas where the private sector has made important contributions.

MONITOR, UNDERSTAND, AND PARTICIPATE IN JAPANESE SCIENCE AND TECHNOLOGY

One important lesson of this project is that in the past lack of knowledge about Japan and complacency about the future have been dangerous for U.S. industry and the nation as a whole. At the same time, improved performance on the part of particular U.S. companies and industries has been aided by exposure to the techniques and accomplishments of Japanese organizations in innovation, and adaptation of some Japanese practices to a U.S. context. Although there is good reason to be pleased with many aspects of U.S. technological and economic performance today, the United States, particularly the science and technology community, must avoid complacency and turning inward in the belief that we have nothing more to learn from the rest of the world. In order to avoid repeating the difficulties of the 1970s and 1980s, it will be necessary to understand at an early stage the new business and technical approaches being developed by Japan and by other countries.

U.S. institutions and citizens should be aware that although U.S. innovation is relatively strong today, continuous effort will be needed to maintain our capabilities. In addition to investment and improved approaches on the domestic side, this increasingly involves accessing and utilizing a global science and technology base, as well as cooperation and competition with international entities.

Despite current challenges, Japan will be the most important country in this process for some time to come, although novel approaches and competitors may emerge from new or unexpected sources.[5] Although there is currently a growing segment of opinion that would write Japan off as a technological and industrial power, the task force reports document Japan's resiliency and continuing strengths in technology and innovation.

Both task force reports deal with aspects of U.S. engagement in Japanese science and technology. The common theme is that effective engagement requires long-term commitment, focus, and investment by both the private and public sectors.

In this regard, the U.S.-Japan Agreement on Cooperation in Research and Development in Science and Technology (U.S.-Japan S&T Agreement) deserves particular attention. The importance of the U.S.-Japan S&T Agreement and U.S. capability to track developments in

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[5] A number of relevant statistics are presented in Chapter 3 of the DTF report and Chapter 4 of the CTF report. Here we will simply note that Japan is ranked second in the world to the United States, with wide gaps to the third-ranked country, in government and private R&D expenditure, number of R&D scientists and engineers, and number of U.S. patents granted. In 1994 Japan was the largest foreign market for U.S. high-technology products (by a slim margin over Canada) and the largest exporter of high-technology products to the United States (by a wide margin, constituting almost 30 percent of high-technology imports). See National Science Board, *Science & Engineering Indicators-1996* (Washington, D.C.: U.S. Government Printing Office, 1996).

Japan will grow in the future. As the United States and other advanced countries are slowing growth in government science and technology spending, Japan has plans for significant increases in the next few years. Budget increases by Japan present an opportunity to leverage investments internationally in areas of basic research and expensive science and technology, like global climate change and health. The U.S.-Japan S&T Agreement should be utilized more proactively than it has been in the past as a mechanism to pursue equitable benefits in the bilateral science and technology relationship. This will mainly require more focus and resources for implementation and monitoring of the agreement on the U.S. side. This also requires encouraging effective program management, developing metrics to track progress in the overall relationship, and ensuring that Japan's rapidly expanding government-funded research efforts are as open as comparable U.S. efforts.

The United States should also maintain stable long-term public and private investments in programs that train U.S. scientists and engineers in Japanese language, send U.S. scientists and engineers to Japan to participate in R&D and manufacturing, and collect and disseminate Japanese science and technology information. Although matching programs and the needs of users has sometimes been difficult, these efforts have produced clear benefits for the participants, and fill a broader national need for capability to track developments in Japan. These programs are modest in size and, in some cases, federal investments leverage significant resources from other sources.

While U.S.-Japan cooperation in defense production and related technologies has traditionally been conducted under a separate policy framework, greater incentive and opportunity for cooperation in defense and civilian technology may also emerge as civilian-derived technologies play a larger role in advanced weapons systems. Taking advantage of these trends will require U.S. focus and commitment. In particular, the Department of Defense should work with the Japanese government and the private sectors of both countries to develop new mechanisms that facilitate technological collaboration between U.S. and Japanese companies to address common defense needs. One possible approach would be a program to fund U.S.-Japan industry R&D on specific enabling technologies, including the adaptation of commercial technologies targeted at applications in future weapons systems.

Finally, there is room for improvement in the Japanese government approach to providing access to science and technology information. Although much science and technology information is available, a great deal of information related to trade and other issues that can affect science and technology cooperation remains difficult to access. The U.S. government should continue to press Japanese government and companies to make certain categories of information, particularly laws, regulations, administrative guidance, and other policy-relevant documents, available to the Japanese and international public, preferably electronically.

A LONG-TERM, INTEGRATED U.S. APPROACH

The United States must continue to build a long-term, integrated strategy to pursuing economic, security, and other interests in science and technology relations with Japan and other key countries. This will involve improved coordination across government agencies, and better communication between the public and private sectors.

The U.S.-Japan science and technology relationship may be a harbinger of broader challenges that the United States will face as scientific and technological capabilities become more global, and as science and technology become more intertwined with the pursuit of the entire range of U.S. national interests. In dealing with Japan-related issues, U.S.-based companies and universities as well as government agencies have had to reexamine and modify

traditional approaches to cooperation. We have been forced to reexamine the balance between short and long-term benefits and risks, and the balance between general and particular interests.

In a pluralistic system such as in the United States, differences of viewpoint are inevitable and desirable. It is unrealistic to expect total coordination among government agencies and between the public and private sectors. However, conflicting agendas and lack of coordination among U.S. entities can be damaging to U.S. interests, and several lessons can be drawn from the experience with Japan to help guide future approaches.

The United States developed new mechanisms for expanded public-private and inter-agency dialogue during the launch of SEMATECH, the response to Japan's Intelligent Manufacturing Systems (IMS) proposal, and in other cases. This experience points to a general need for expanded coordination on national and international science and technology issues that will become more apparent in coming years. As has been the case regarding Japan relationships, the United States will at times face short-term dilemmas in balancing pursuit of economic, security, and other interests. It will be important to continue and extend the efforts that have been made in the area of Japan policy to coordinate and integrate the agendas of the various agencies on an ongoing basis. It will also be important to maintain a focus on long-term strategy for science and technology cooperation with Japan and the rest of Asia that integrates both economic and national security interests, and involves significant, ongoing private sector input.

Although U.S. innovation appears to be strong today, maintaining our strength will depend on continued efforts to improve our performance in translating research into superior products and services. U.S. industry, universities, and government should continue to increase investments in science and technology and develop new collaborative mechanisms that increase the economic returns on this investment. Partnerships focused on important commercial technologies linked with agency or broader national needs should be a particular priority.

In addition, the Department of Defense should ensure a coordinated approach with other government agencies and appropriate private sector organizations in future collaborative defense programs with Japan. One approach that might be adopted as a minimum is designating a single authority within DOD with the responsibility for coordinating strategies toward major systems in which collaboration with Japan is under discussion. In the future, if conditions warrant it, the DOD might consider adopting a more formal mechanism such as an International Programs Coordinating Council analogous to the Joint Requirements Oversight Council.

Further, the United States and Japan should institute an enhanced comprehensive security dialogue featuring an integrated discussion of the political-military, economic, technological, and other aspects of the relationship. Such a dialogue would lead to enhanced discussion across sectors in both countries focused on the long-term prospects and issues in U.S.-Japan relations.

Neither task force recommended major changes in U.S. government budgets and organization for cooperation with Japan in science and technology, or in the official structure of U.S.-Japan agreements. Most of what needs to be done by the U.S. government to ensure that cooperation with Japan advances long-term U.S. interests can be accomplished through stable funding for current programs and more focused U.S. implementation of existing agreements. The policy frameworks for civilian and defense science and technology cooperation with Japan remain largely separate. The political and historical reasons for this separation are understandable. However, greater cooperation and leveraging of effort across U.S. civilian and defense agencies in science and technology cooperation with Japan is necessary over the long term. This is due to shifts in the environment documented in the task force reports, such as the increasing reliance of defense systems on commercially-derived technologies, and the growing imperative that government operations and programs operate efficiently and cohesively. Joining forces and activities is a step in that direction. Changes in the political environment in Japan may make it possible to overcome long-standing barriers to new approaches. The key U.S. players responsible for the civilian and defense aspects of official science and technology relations should consider

establishing a regular exchange to explore new approaches that could be implemented unilaterally or discussed with Japanese counterparts.[6]

EPILOGUE

The U.S.-Japan relationship both past and present can be considered a leading indicator of issues and questions that may emerge in relations with other countries, particularly the emerging techno-industrial powers of Asia. Inattention to technological and industrial trends and approaches of other countries could lead to serious challenges to national interests and U.S.-based institutions in the future. Tracking developments in Asia and developing cooperative strategies will take on increasing importance for the United States. Even U.S.-Japan cooperation and competition is taking on an increasing Asia dimension.

The Japan experience also highlights the important general point that as global capability and competition in science and technology increase, the capability to generate and utilize innovation to create new products, companies, and markets, is perhaps the most important key to national well-being and prestige. The role of natural advantages such as mineral resources and geography will change, as nations increasingly focus on building their knowledge base, brain power, and technical infrastructure of institutions and facilities.

Erich Bloch
Chairman, Committee on Japan

[6] For the purposes of this discussion, the "key U.S. players" are the U.S. members of the Joint High Level Committee, Joint High Level Advisory Panel, and Joint Working Level Committee under the U.S.-Japan S&T Agreement, and the U.S. representatives to the Systems and Technology Forum which is involved with defense-related R&D cooperation. But these discussions could include others as appropriate.

Report of the Competitiveness Task Force
Executive Summary

OVERVIEW

In the late 1980s and early 1990s, Japan's economic and technological strength was an object of admiration and concern in the United States and elsewhere. Japanese companies had established leading positions in the global market for critical high-technology products, such as semiconductor memories, and dominated the production of key semiconductor manufacturing tools. Japanese industry and government appeared poised to build on accumulated strength in consumer electronics and electronic components to establish a leading position in the emerging synthesis of computing and communications, one of the key growth industries for the next century. Even in areas where Japan was presumed to lag, such as the aircraft and biotechnology industries, cooperative industry-government research partnerships and research collaboration with U.S. universities and companies were pursued aggressively. It appeared to be only a matter of time before Japanese companies would emerge at the forefront of these industries as well.

Juxtaposed with Japan's high-technology juggernaut, the United States appeared to be in serious decline as an economic and techno-industrial power. U.S. industry was experiencing increasing difficulty in translating the outputs of America's formidable research and development effort into globally competitive products, high-wage jobs, and an improved standard of living. Large economic imbalances with Japan in trade and investment contributed to this picture of relative decline.

The prospect that Japan might come to hold increasing sway over high-technology industries raised concerns about the long-term impacts on U.S. economic well-being and national security. One area of focus was the U.S.-Japan science and technology relationship. While U.S.-Japan interaction in science and technology is extensive and comprises a variety of counterparts and mechanisms, it is also widely imbalanced and asymmetrical in terms of the flow of people, knowledge, and many technology-based products.[1] There is a sharp contrast between the effective utilization of U.S. science and technology often exhibited by Japanese companies and the low level of Japanese science and technology utilization by U.S. entities. As Japan's standing in technology-based industries continued to grow and the United States suffered reverses, some questioned whether continued asymmetrical science and technology relationships would impair America's future capability to produce and utilize innovation, the mainspring of future growth in productivity and economic performance.

With these concerns as a backdrop, the National Research Council's Committee on Japan formed the Competitiveness Task Force to assess the U.S.-Japan science and technology relationship and to develop recommendations on what the U.S. government, industry and research institutions should do to maximize the economic benefits to the United States of science and technology interaction with Japan in the future. For its assessment the task force examined the historical experience of U.S.-Japan science and technology relationships and their impact on competitiveness and economic performance, the current policy context, and U.S.-Japan

[1] Chapter 4 contains relevant tables and figures.

competitiveness trends in key industries. The present report is part of a larger study by the Committee on Japan of the U.S.-Japan science and technology relationship.[2]

The task force addressed two key questions. First, are there structural features of the U.S.-Japan science and technology relationship that affect U.S. capabilities to produce and utilize innovation? Second, are there general lessons and insights to be drawn from the U.S. experience with Japan that could be applied to international science and technology relationships in the future? Although the broader issues related to America's economic future and the role that science and technology will play in shaping that future are outside the scope of this study, the task force hopes that this effort contributes to discussion of those issues.

From today's perspective, the environment that gave rise to concerns over the link between U.S.-Japan science and technology relations and U.S. economic performance has shifted considerably. Japan's economy and its technology development complex have faced serious difficulties in recent years, while the United States has experienced something of a high-technology resurgence. Concerns about the U.S.-Japan science and technology relationship have died down for the time being. The conventional wisdom about future prospects for the U.S. and Japanese economies has taken a 180 degree turn.

Despite these shifts in the prevailing mood, the task force believes that science and technology relations with Japan continue to have significant implications for the U.S. economy and will be more important in the future than is currently perceived. Companies and industries based in Japan will continue to be formidable global competitors, and Japan is taking a number of steps to address the challenges it currently faces. A notable ongoing development is the redoubled effort by the Japanese government to strengthen fundamental research capabilities through increased funding and related policy changes. The task force also believes that the U.S. industrial and high-technology ascendancy apparent today is not a permanent state of affairs. Not only Japan but also emerging industrial powers such as Korea and China will produce strong competitiveness challenges for the United States in the future.

Since U.S. policy debates over science and technology relations are not as heated or contentious today as they once were, the task force was able to focus more sharply on long-term trends and issues. Hopefully, the findings and recommendations developed here will contribute to building U.S. approaches to competition and cooperation with Japan in science and technology that strengthen U.S.-based innovation capabilities and allow maximum long-term benefits to flow to this country's economy and citizens.

MAJOR FINDINGS

Science and Technology Interactions Have Had a Considerable Impact on Economic Performance

The acquisition, effective adaptation, and improvement of technologies from abroad, mainly from the United States, served as a basis for Japan's rapid economic growth and international competitiveness in a wide variety of manufacturing industries. For the United States the economic benefits of science and technology interactions with Japan have been much lower in relative and absolute terms, but there are indications of growing benefits in recent years.

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[2] While this report focuses on U.S. competitiveness and economic interests, a previously released companion report deals with U.S. national security interests. See National Research Council, *Maximizing U.S. Interests in Science and Technology Relations with Japan: Report of the Defense Task Force* (Washington, D.C.: National Academy Press, 1995).

The science and technology interactions between Japan and the United States that have had a considerable impact on the economic performance of the two countries have occurred predominantly in the private sector. They include licensing agreements and collaborative engineering ventures between companies and the activities of multinational corporations. From the end of World War II until well into the 1970s, Japanese government controls over trade and foreign direct investment allowed a coordinated industry-government approach to obtaining technologies from foreign companies in return for limited market access and licensing fees. The electronics and computer industries provide the best examples of how this approach worked. Japanese industry, through the development of superior production and enterprise systems, put foreign know-how to work in both established and new markets, thereby transforming imported technology into wealth and economic security.

At the same time, the ability of U.S. companies to participate in the Japanese market was often blocked or impaired by Japanese industry or government-industry cooperation. Barriers to market participation lowered the returns that U.S. innovators received on technology investments; prevented learning and technology development opportunities that would have occurred through interaction with sophisticated Japanese customers; and greatly reduced incentives for U.S. companies to build organizational capabilities for manufacturing, marketing, and participating in innovative activities in Japan. In several extreme cases this had a negative effect on the long-term ability of U.S. companies to sustain technological, product development and manufacturing capabilities in the United States.

More recently, U.S. companies have greatly improved their manufacturing and product development performance in response to Japanese competition. Japanese manufacturing investment in the United States has increased the productivity and technology levels of several industries and has provided high-wage employment. Although benefits and costs are difficult to quantify, Japanese investments in U.S. research and development activities and in small high-technology companies and U.S. universities in such fields as biotechnology and instrumentation have provided additional resources for U.S.-based innovation and to date do not appear to have caused measurable harm to U.S. capabilities.[3]

The U.S.-Japan Science and Technology Relationship Is Changing

In recent years a number of major changes have occurred in the U.S.-Japan science and technology relationship, most of them positive from a U.S. perspective.

The strengths of the U.S. innovation and market systems have reasserted themselves, particularly but not exclusively in information-related industries. A wide range of U.S. manufacturing companies have developed more effective approaches to innovation, manufacturing, and marketing, in some cases adapting aspects of Japanese practices. There are now a considerable number of U.S. scientists and engineers with Japanese language capabilities and experience in Japanese laboratories and manufacturing facilities, and it is the task force's judgment that they have enhanced the ability of various U.S. organizations to understand and interact effectively with Japan.

At the same time, the twin pressures of global market forces and U.S. trade policy initiatives have encouraged Japanese companies to enter into more reciprocal international relationships than they did in the past, albeit from a very low base. Japanese government and industry strategies to further strengthen Japan's leading role in global high-technology development and

[3] Japanese-owned R&D labs are contributing to the current fierce competition in the United States for human resources in areas related to information technology, but most task force members would not characterize this as "harm."

manufacturing have met with diminishing returns recently, owing to the loss of the most effective policy tools for limiting market access. Approaches to industrial development based on technology acquisition and improvement have become less effective due to the higher risks and uncertainties faced by Japanese companies as they have reached the technological frontier. Japanese firms also have faced challenges from new technological and industrial competitors in markets where they had established strong positions, such as semiconductor memories.

But Important Asymmetries Continue to Exist

Although the structural asymmetries in the U.S.-Japan science and technology relationship appear to have a less harmful impact on particular U.S. companies and industries now than was the case in the past, wide imbalances still exist. Opportunities for U.S. companies to fully participate in the Japanese market are still constrained in a number of high-technology industries. Statistics on personnel exchanges, technology licensing agreements between unaffiliated companies, and other aspects of the relationship reflect continued asymmetries. Therefore, a clear focus by policymakers and corporate managers on addressing these asymmetries will continue to be important.

Barriers to market entry, now mainly nontariff barriers stemming from Japanese policies and business practices, still have the effect of limiting or filtering U.S. access to Japanese markets, technologies, and technological capabilities. Recent Japanese government and industry initiatives, particularly in the microelectronics and information sectors, indicate that traditional strategies to advance the interests of Japanese companies in the global economy continue to be used. Japan is also developing new approaches to government-industry partnership to better harness science and technology to build a stronger and smarter Japanese economy. Some Japanese policies and business practices continue to limit the ability of U.S.-based companies to fully participate in the Japanese market, and therefore may also limit the ability of the U.S. economy to innovate and create wealth and high-wage jobs.

Japan Will Continue to Be a Major Partner and Competitor

Japan-based companies, and most likely Japan as a location for research, innovation, and manufacturing, will remain formidable.

Despite recent setbacks in competitiveness and technology development, the task force believes that Japanese companies will remain among the leading international competitors and collaborators for U.S. industry in a range of high-technology manufacturing and service industries and will manufacture and compete globally. Although companies based in Korea, Taiwan, and elsewhere in Asia have made impressive gains, Japanese companies are likely to remain among the world's premier manufacturers. A number of them are already making successful transitions from manufacturing primarily in Japan to coordinating efficient global production networks. The task force believes that the current effort by the Japanese government to increase support for fundamental research will lead to noticeable gains in the depth, breadth, and quality of Japanese research over the next decade. Finally, the Japanese public and private sectors are expanding their efforts to forge advantageous international linkages in science and technology, particularly in Asia.[4]

[4] Several task force members noted recent alliances involving significant Japanese technology transfer to Asian counterparts and questioned whether Japanese approaches to Asia will ultimately be more effective than those of the United States.

U.S. Government Policies Should Be Oriented Toward the Long-Term and Should Incorporate Industry Perspectives

Future relations with Japan in science and technology can advance U.S. economic interests and involve greater mutual benefit than has been the case in the past, but formulating appropriate U.S. strategies requires a long-term perspective and consistent policy approach. Policymaking should include participation by U.S. industry.

Although the U.S. position in technology and competitiveness relative to Japan appears to be much different than it was five years ago, it would be a mistake to assume that current conditions will continue indefinitely. U.S. government and industry should set future policies not according to the current mood, whether that be hubris or pessimism, but according to the long-term imperative of building domestic capabilities and international relationships in science, technology, and innovation that sustain and enhance wealth creation and high-wage employment in the United States. In particular, U.S. government and industry should continue efforts to build a more reciprocal U.S.-Japan science and technology relationship. Just because the relationship has featured wide asymmetries in the past that continue today does not mean that this must be the case in the future.

Key Challenges Are Emerging in Asia

Many of the key future challenges facing the United States and Japan in ensuring that international science and technology relationships enhance domestic economic performance lie in Asia.

Asian high-technology markets are growing more rapidly than Japan's, and Asian companies are challenging Japanese dominance in a number of critical manufacturing industries. Japanese and U.S. industry efforts to invest in and tap Asian markets and capabilities are growing as well. Ties with Asia will become increasingly important for both countries, and for the U.S.-Japan relationship, raising three critical questions for the future:

- How will the Japanese industrial and technological presence in Asia affect U.S. interests in the future?

- How can the U.S. experience in dealing with Japan (positive and negative lessons) be applied to approaches toward emerging Asian economies?

- To what extent will the United States and Japan share common interests in Asia, with opportunities for expanded cooperation and expanded Japanese contributions to science and technology that benefit the region and the world?

These questions are beyond the scope of this report. Nevertheless, the task force believes that its priorities and recommendations for U.S.-Japan relations are broadly applicable to science and technology relations with other rapidly emerging economies, including those of Asia.

PRIORITIES FOR THE UNITED STATES AND POLICY RECOMMENDATIONS

Continue Public Support for National Capabilities Needed to Access and Utilize Japanese Science and Technology

From its broad assessment of U.S.-Japan personnel exchange and information programs in science and technology, the task force believes that these efforts have made an important contribution to U.S. capabilities to gain benefits from science and technology cooperation with Japan. These efforts have delivered specific benefits to users and participants, and over time have contributed to developing national capabilities that should be maintained. Although in some cases it has proven difficult to match programs and activities with specific user needs, several activities have achieved solid success over a considerable period. In addition, U.S. government investments are well leveraged with support from other sources. Therefore, the relatively modest public investments in Japanese language training and Japanese research opportunities for U.S. scientists and engineers, and in efforts to collect and disseminate Japanese scientific and technological information, should be maintained on a stable, long-term basis.

Recommendations

1. Stable, long-term U.S. government investment in a group of Japan-capable scientists and engineers should be maintained, particularly where limited U.S. investments leverage significant amounts of Japanese funding.

Unlike U.S. relations with other Asian countries, where top U.S. educated Asian scientists and engineers frequently stay in the United States or can be hired by U.S. organizations, prevailing patterns of education and employment have served to impair U.S. access to Japanese science and technology. Continued public investment in a group of U.S. scientists and engineers proficient in the Japanese language and experienced in Japanese laboratories and manufacturing facilities will facilitate an expanded flow of information to the United States. Even in cases where participants are not immediately hired into positions working directly on Japan issues, their Japan-related skills and experience are often increasingly utilized over time. The modest level of public investment in recent years through programs of the National Science Foundation and the Air Force Office of Scientific Research has been effective and well leveraged. As scientists and engineers with Japan-related skills and experience advance in their industrial, academic, and government careers, their international perspective and capabilities will also contribute to U.S. ability to understand and participate effectively in technological relationships with other Asian countries. The need to train scientists and engineers in other languages and cultures, particularly those of Asia, also should be assessed.

2. The U.S. government should maintain support for efforts to obtain, translate, and disseminate Japanese scientific, technical, business, and policy information.

The Internet and related technologies enable a wider group of U.S. scientists, engineers, and businesspeople to access Japanese information quickly and easily.[5] The small amount invested in U.S. government programs can achieve a large payoff in terms of increased awareness of science and technology developments in Japan. The U.S.-Japan machine translation center at the U.S. Department of Commerce is a recent positive example. U.S. government agencies should

[5] By the same token, U.S. information is also easier to access by scientists and engineers in Japan and elsewhere, perhaps at a greater rate than that of other countries because of the wider diffusion of Internet participation in the United States.

continue their efforts to coordinate among themselves, with a focus on ensuring that electronic resources are linked when possible, and cooperate with private-sector entities to ensure relevance to industry needs and the availability of materials in electronic form. The Commerce Department's Asia Technology Program should serve as the central clearinghouse and coordinator for these leveraging and linkage efforts.

3. The U.S. government should continue to press the Japanese government and Japanese companies to make certain categories of information that affect market participation and technology relationships, particularly laws, regulations, administrative guidance, and other policy-relevant documents, available to the public, preferably electronically.

The ability of companies based outside Japan to compete in the Japanese market is often impaired by a lack of access to relevant information that is shared informally among Japanese government and industry insiders. Making these categories of information available electronically, even in Japanese, would not solve all of the problems of access to Japanese markets, but it would enhance the ability of at least some U.S. companies to compete. Most Japanese agencies now have home pages on the World Wide Web, which could be used in making information more widely available.

4. A number of U.S.-based companies and industry associations have advanced their interests through capability to monitor developments in Japan and participate in policy processes. U.S. industry should redouble efforts to expand access to the Japanese market and Japanese technology and seek a greater role in Japanese and U.S. policy debates.

Positive examples include the American Electronics Association's Tokyo office, the American Chamber of Commerce presence in Japan, U.S. companies that have established a strong strategic and policy capability in Japan, and the U.S. software industry's role in discouraging changes in Japan's copyright law that might have allowed unrestricted decompilation and marketing of reverse engineered software products.

Renew Efforts to Engage Japan in Science and Technology Relationships That Deliver Equitable Benefits

The task force believes that Japan will follow through on its stated goal of sharply increasing public spending on science and technology over the next several years. Although changes in approach on the part of Japanese institutions will be necessary in order to translate this increased funding into a strong fundamental research base, the task force is optimistic about the future of Japan's science and technology capability. Because the Japanese science and technology budget is rising rapidly and growth in the U.S. budget will be constrained at best, now is precisely the time that the U.S. private and public sectors should renew efforts to engage Japan in equitably beneficial cooperation. Active utilization of the U.S.-Japan Agreement on Cooperation in Research and Development in Science and Technology (U.S.-Japan S&T Agreement) should be a particular focus.

Recommendations

5. The U.S. government should actively use the U.S.-Japan S&T Agreement to advance U.S. interests by encouraging effective program management, developing metrics to track progress in the overall relationship, and ensuring that Japan's new publicly funded research efforts are open.

Although ensuring reciprocity and equitable benefit in science and technology relationships is mainly the responsibility of the agencies, companies, universities, and research institutes that

are themselves involved in research collaboration, the U.S. government can use the U.S.-Japan S&T Agreement more actively to advance U.S. interests. One focus of U.S. preparation for joint U.S.-Japan meetings under the agreement should be review of individual agency programs to encourage effective management. The United States and Japan should also develop a simple set of metrics in areas such as scientific and engineering personnel exchanges funded by each government, public funding of collaborative projects, participation by U.S. companies in Japan's publicly funded R&D programs (and vice versa), and intellectual property created by collaborative programs. These could be updated annually as part of the administration of the agreement. Finally, the United States should continue to use the agreement to ensure that, as Japan increases public science and technology investments, these new programs and institutions are as open to international participation as U.S. fundamental research.

6. The United States should encourage expanded Japanese contributions in science, technology, and other cooperation that creates global benefits.

Japan's efforts to revitalize its research base, especially the research capabilities of universities, will provide new opportunities for U.S.-Japan cooperation in science and technology to create global benefits in policy areas such as encouraging adequate protection of intellectual property rights. In the future the extent of Japanese contributions to basic research and to the training of scientists and engineers worldwide should be regarded as an important measure of the health of the U.S.-Japan relationship. Japan should be encouraged to exercise increased leadership, building on recent positive efforts such as the Human Frontier Science Program, an effort launched by Japan to fund fundamental research in the life sciences.

7. U.S. companies and the U.S. government should utilize lessons from dealing with Japan in their dealings with emerging techno-industrial powers.

A number of lessons can be drawn from the experience of U.S. companies that have derived concrete long-term benefits from their collaboration with Japanese partners and efforts in the Japanese market. Careful protection and management of intellectual property rights in the United States and in other markets, gaining direct access to customers, building market participation "tollgates" into technology transfer agreements, focused training for engineers assigned to joint projects, and other approaches can help ensure that collaboration leads to sustainable competitive strength.

Increase the Economic Benefits from U.S. Science and Technology Through Enhanced Industry-University-Government Cooperation

Since the early 1980s, partly in response to the global competitive challenge led by Japan, the United States has developed a number of new programs and approaches to enhancing cooperation between industry, university, and government sectors in research, development, and commercialization. Overall, this effort has been very successful and has allowed faster and more effective commercialization of U.S. science and technology. Other countries, including Japan, are drawing their own lessons from the U.S. experience and developing their own new approaches to increase the economic benefits of science and technology through better intersectoral collaboration.[6]

In addition to maintaining and increasing overall levels of public and private investment in science and technology, the United States must continue to focus on improving the return on these investments. This is no time to rest on our laurels. Improving industry-university-government collaboration continues to be a key imperative. Although some aspects of federal

[6] For example, while large R&D consortia have previously featured strong Ministry of International Trade and Industry leadership, one of the new projects in microelectronics is being undertaken under private-sector leadership.

support for R&D partnerships with industry focused on commercial technologies are controversial, government clearly has an important role in encouraging industry and universities to work together on long-term, high-risk research, particularly in areas linked to agency and broader national goals. In the United States, SEMATECH has contributed to the U.S. resurgence in microelectronics. An area in which the Japanese government is making major investments is intelligent vehicle and highway systems, which promise to deliver competitive advantage to auto manufacturers while improving national transportation systems. The United States should foster an environment in which new approaches to collaboration can be tried.

Another issue that arises in relation with civilian technology programs is the terms by which foreign companies should be allowed to participate. The United States and Japan have very different approaches to organizing projects. The United States tends to rely on transparent competitive mechanisms, while many Japanese projects are developed through close industry-government consultation far in advance of a project being budgeted. Several prominent Japanese projects have included foreign participation in recent years, and the task force recognizes that advancing a national science and technology agenda will increasingly involve tapping the capabilities of global companies based outside the United States. However, the task force does not agree on what approach the United States should take to foreign participation in the short term. At the moment, U.S. programs have a range of performance requirements that apply to all members and reciprocity requirements for foreign-based participants. Some task force members believe that the United States should unilaterally eliminate these reciprocity requirements and grant national treatment. Others believe that until multilateral rules are developed in this area the principle of reciprocity is important to uphold, particularly when the rules of other countries, such as Japan, are not always clear. The task force also recognizes that the definition and value of "foreign participation" in the two countries is probably quite different.

Recommendation

8. U.S. industry, universities, and government should continue to increase investments in science and technology and should develop new collaborative mechanisms that increase the economic returns on this investment. Partnerships focused on important commercial technologies linked with agency or broader national needs should be a particular focus. Resolving the issue of foreign participation in such programs, and participation by U.S.-based companies in foreign government programs, is a pressing task for the future.

Expand Market Opportunities for U.S. Science and Technology-Based Products in Japan and Globally

As this report documents, access barriers to the Japanese market have played a major role in the differential economic benefits that Japan and the United States have derived from science and technology cooperation. Expanding opportunities for sales in foreign markets of U.S. science and technology-based products is increasingly essential to maintaining U.S. capabilities to generate and utilize innovation. As this study documents, global market participation is critical because (1) demanding customers spur technology development; (2) market participation allows the development of organizational capabilities in companies; (3) market participation increases the revenue base for investment in efficient manufacturing, services, and technology development; (4) international competitors are prevented from establishing a domestic "profit sanctuary"; and (5) head-to-head competition sharpens capabilities in research and development, manufacturing, and marketing.

Regarding U.S. trade policy, task force members have a range of views on whether past bilateral trade initiatives with Japan have been effective and the relative importance that should be placed on bilateral, regional, and multilateral approaches in future U.S. trade policies. The task force is very much in agreement that the launch of the World Trade Organization (WTO) represents a major test for the United States and other trading nations and that an effective WTO would greatly advance U.S. interests. If the enhanced dispute settlement powers and other provisions of the Uruguay Round do meet expectations, future multilateral trade negotiations could address areas that will expand market participation. Trade and investment, and trade and competition policy, are likely to be the two highest priorities.

The task force believes that improving global intellectual property protection is another key priority for the United States. Trade-related intellectual property measures were addressed in the Uruguay Round, and the harmonization of patent systems is being pursued through the World Intellectual Property Organization. The difficulties that U.S. companies have experienced in gaining effective intellectual property protection in Japan show that the interpretation and enforcement of intellectual property laws is just as important as the legal provisions themselves.[7] The United States will need to continue to pay particular attention to intellectual property protection in a global marketplace, effectively pursuing multilateral initiatives while dealing with individual countries when specific issues arise.

The task force also believes that Japan and the United States will share common interests on an increasing number of global trade issues. In promoting adherence to multilateral rules by developing countries and working to develop common approaches to emerging issues such as trade and the environment, the United States and Japan can contribute to further positive development of the world trading system. This is of major importance to both countries.

Recommendations

9. Effective implementation of the Uruguay Round will advance U.S. interests considerably. In future multilateral negotiations the United States should focus on areas where barriers to participation in the Japanese market continue to arise: direct investment and competition policy.

10. The U.S. Trade Representative's Office, the U.S. Patent and Trademark Office, and U.S. industry should develop a process to identify patent applications by U.S. citizens in Japan and perhaps other countries that cover major scientific and technological advances, to ensure that these critical patents receive timely and effective protection.

In 1994 the United States concluded important agreements with Japan on intellectual property protection designed to address some of the most serious problems U.S. innovators have experienced with the Japanese system. The provisions are being implemented on a prearranged timetable. As part of the follow-up to this agreement and as a broader initiative to ensure that critical U.S. innovations receive timely and effective protection around the world, a "watch list" of such applications should be established. Inventors of potentially important innovations could

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[7] Intellectual property protection is an important focus of this report. Industry-specific issues in biotechnology and information industries are covered in Chapter 5. The committee believes that the overall strengthening of U.S. patent protection since about 1980 has benefited U.S. innovators, particularly the unification of appellate jurisdiction in the U.S. Court of Appeals for the Federal Circuit. Differences in the U.S. and Japanese intellectual property systems, and problems faced by U.S. innovators seeking protection in Japan, are covered in U.S. Congress, General Accounting Office, *U.S. Companies' Patent Experiences in Japan* (Washington, D.C.: U.S. Government Printing Office, 1993), and National Research Council, *Corporate Approaches to Protecting Intellectual Property* (Washington, D.C.: National Academy Press, 1994). The United States and Japan reached two agreements on intellectual property in 1994, which are described in U.S. Trade Representative, *1994 Annual Report* (Washington, D.C.: U.S. Government Printing Office, 1995).

apply for a place on the watch list. Problems in gaining timely and effective patent protection might be identified at an early stage and addressed through government-to-government consultations. Serious delays or limitations in protection could be addressed through trade actions. This program might be linked to efforts to expand opportunities for U.S. industry, particularly small and medium companies, to access Japanese markets by making information about intellectual property rights in Japan available to companies.

11. The United States should explore areas for cooperation and coordination in trade policy and in other areas with Japan and other countries to promote more open access to markets and economies in developing countries. As more developing countries recognize the value of foreign direct investment in raising their technology levels, the United States and Japan can have a greater impact when working together to encourage adherence to multilateral rules, and to discourage national approaches that feature focused technology transfer as a condition for market participation. The United States and Japan should also work to develop common approaches to emerging issues on the multilateral agenda, such as trade and the environment.

1
Introduction

CONTEXT

More than a decade ago, long-standing negative trends in the competitiveness of U.S. industry and the U.S. economy became the focus of widespread concern and debate.[1] By the early 1980s, a decline in U.S. macro- and microeconomic performance relative to our major trading partners—a decline steeper than what might have been expected from normal catching up by other countries—had become apparent. The macroeconomic problems included stagnant growth in productivity and overall output and a growing merchandise trade deficit. On the microeconomic side, American companies and industries that had once led the world experienced significant erosion of domestic market share by imports, resulting in plant closings, layoffs, and demands for trade protection.

The comforting belief that the United States could rely on its preeminence in high technology to fuel growth in new, high-value-added industries was shaken when the U.S. semiconductor industry suffered severe setbacks in the mid-1980s. *It became clear that in the future leadership in scientific and technological research alone would not guarantee for the United States a leadership role in the commercialization of innovation or the lion's share of the wealth created by new technology-based industries.*[2] The continuation of these negative trends held significant unattractive implications for American living standards, overall economic well-being, and national security.

To a large extent, the concerns and anxieties arising from the competitiveness problem were focused on Japan, both as the nation representing the most serious techno-industrial challenge and as a reference point for America's shortcomings. In nearly all of the major manufacturing industries where U.S. companies have experienced severe international competitive challenges—textiles, steel, consumer electronics, automobiles, semiconductors, and machine tools—import competition came first and foremost from Japanese companies.[3] The U.S. merchandise trade deficit with Japan rose from less than $3 billion in 1975 to over $56 billion in 1987, the latter figure comprising over one-third of the record U.S. merchandise trade deficit of $152 billion for

[1] For an early academic treatment, see John Zysman and Laura Tyson, eds., *American Industry in International Competition* (Ithaca, N.Y.: Cornell University Press, 1983). Growing interest and concern in the early 1980s culminated in the formation of a presidential commission to study the competitiveness problem. This group is widely referred to as the Young Commission after its chairman, John Young. See President's Commission on Industrial Competitiveness, *Global Competition: The New Reality* (Washington, D.C.: U.S. Government Printing Office, 1985). On p. 6 the report defines "competitiveness" as "the degree to which a nation can, under free and fair market conditions, produce goods and services that meet the test of international markets while simultaneously maintaining or expanding the real incomes of its citizens."

[2] The Young Commission identified four areas of policy focus—technology, capital resources, human resources, and international trade. Ibid.

[3] Except in a few cases, such as Airbus in commercial jet aircraft, the European challenge that was anticipated by some in the 1960s and 1970s has largely failed to materialize.

that year.[4] Many U.S. manufacturing companies were hampered by outdated strategies, short time horizons, technological shortcomings in product development and production, business-government antagonism, and other ills.[5]

The Japanese economy and Japanese companies, on the other hand, were on a long and impressive winning streak. Possessing a highly skilled and cooperative work force and an effective government-industry partnership, including financial and regulatory structures, Japanese industry appeared to move from strength to strength during the 1970s and 1980s. Japan's major manufacturing industries became leading world exporters, with gains in the export of high-technology products originally developed in the United States especially conspicuous. Japanese companies were seen as embodiments of management skill and insight, and Japan's economic and industrial policymaking appeared to represent a superior model of government-facilitated capitalist development.[6]

Reflecting growing admiration and anxiety over Japan's advances in high-technology industries, the U.S.-Japan science and technology relationship began to attract increasing attention from U.S. policymakers and private-sector leaders in the mid-1980s. The focus sharpened on long-standing asymmetries in scientific and technological relations between the United States and Japan, particularly imbalances in technology flows and exchanges of scientific and engineering personnel.[7] Throughout most of the period from the end of World War II until the 1980s, the United States saw scientific and technological relations with Japan mainly as a means for deepening and improving political and human relations between the two countries—a nonproblematic aspect of overall foreign policy. Indeed, this is how the United States has traditionally handled scientific and technological exchanges with other friendly nations.[8] The U.S. security alliance with Japan reinforced the linkage between science and technology relations and foreign policy goals.[9]

Science and technology relations with Japan became linked to the competitiveness and trade debates in two related areas. First, Japan's growing prowess in high-technology industries and the example of effective Japanese utilization of technologies developed in the United States prompted suggestions that the U.S. private sector would benefit from monitoring and assimilating technological and managerial developments in Japan and that government might encourage such efforts.[10] A second area of focus emerged from the realization that U.S.-developed technologies

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[4] U.S. Bureau of the Census data. The last year in which the United States ran a merchandise trade surplus was 1975. The trade deficit with Japan reached $65 billion in 1994.

[5] Michael L. Dertouzos, Richard K. Lester, Robert M. Solow, and the MIT Commission on Industrial Productivity, *Made in America: Regaining the Productive Edge* (Cambridge, Mass.: MIT Press, 1989).

[6] See James C. Abegglen and George Stalk, *Kaisha: The Japanese Corporation* (New York: Basic Books, 1985); Akio Morita with Edwin M. Reingold and Mitsuko Shimomura, *Made in Japan: Akio Morita and Sony* (New York: E.P. Dutton, 1986); and Chalmers Johnson, *MITI and the Japanese Miracle: The Growth of Industrial Policy, 1925-1975* (Stanford, Calif.: Stanford University Press, 1982).

[7] These imbalances are described in more detail below. See also National Research Council, *Maximizing U.S. Interests in Science and Technology Relations with Japan: Report of the Defense Task Force* (Washington, D.C.: National Academy Press, 1995), particularly Chapter 3.

[8] For example, the U.S.-Japan Cooperative Science Program was launched in 1961, and is the oldest international cooperative program in which the United States participates. As the first bilateral science and technology agreement, it set the pattern for utilizing science and technology as a foreign policy tool. See the United States-Japan Committee on Scientific Cooperation, *Twenty-Year Report: 1961-1980* (Tokyo: Japan Society for the Promotion of Science, 1982).

[9] See National Research Council, op. cit.

[10] U.S. House of Representatives, Committee on Science and Technology, *The Availability of Japanese Scientific and Technical Information in the United States* (Washington, D.C.: U.S. Government Printing Office, 1984). The growing interest in Japanese science and technology in the early 1980s was reflected in the establishment of the Massachusetts Institute of Technology's Japan Program and other efforts to train American scientists and engineers in the Japanese language.

that had been acquired and improved by Japanese industry over the years constituted a significant component of overall capability for a number of Japanese industries that were challenging U.S. leadership. In addition to emphasizing U.S. access to and utilization of Japanese technology, prospects for a continuation in lopsided science and technology relations between the two countries raised additional concerns among some about Japanese access to U.S. know-how and technology, particularly the trade-related impacts.[11] The balance of risks and benefits from continued open access to U.S. basic research was questioned.

That is the context in which this study was conceived and planned. The National Defense Authorization Act of 1992-1993 called for a comprehensive assessment of the U.S.-Japan science and technology relationship by the National Academy of Sciences.[12] In conducting the study the National Research Council's Committee on Japan organized the Competitiveness Task Force to examine U.S. economic and competitiveness interests at stake in the science and technology relationship with Japan. A parallel task force examining U.S. national security interests completed its report in 1995. The Committee on Japan integrated the two reports into a framework for maximizing U.S. interests. This "overview study" was undertaken with support from the Departments of Commerce, Defense, Energy, and State as well as the National Science Foundation.

RECENT TRENDS

As the Competitiveness Task Force was formed and started its work in early 1994, it was clear that many of the factors outlined above that contributed to the U.S.-Japan competitive and technological trends of the 1980s and early 1990s had shifted considerably. At this writing, although Japan has officially emerged from the post-bubble recession of 1992-1995, economic growth remains sluggish and appears vulnerable to the continuing drag of asset deflation and related problems in the financial system.[13]

In addition, the strategic comeback that has been achieved by a number of U.S. companies in industries that have experienced tough competition from Japan—most notably semiconductors and automobiles—continues and appears to be based on substantive improvements in business performance, including manufacturing and technology commercialization, as well as differences in business cycles and currency fluctuations. Japanese companies have not yet made significant inroads in high-technology industries that had been the focus of Japanese government policies and corporate strategies during the 1980s, such as biopharmaceuticals. Japanese companies have not gained significant ground overall in the computer and software industries, despite persistent efforts and success in certain segments such as games software. Furthermore, Japanese companies are being challenged by Korean and other Asian companies in areas where they had established clear dominance, such as dynamic random-access memory, and Korean companies are gearing up to take on the Japanese companies that currently dominate flat panel display manufacturing.

[11] The difficulties experienced by the U.S. semiconductor industry in the mid-1980s, and corresponding gains by Japanese industry, were particularly important in catalyzing these concerns. The revamping of the U.S.-Japan Science and Technology Agreement to include new oversight mechanisms, intellectual property provisions, and other features also reflected these trends. The agreement is covered in more detail in Chapter 4.

[12] U.S. Senate, Committee on Armed Services, *National Defense Authorization Act for Fiscal Years 1992 and 1993* (Washington, D.C.: U.S. Government Printing Office, 1991), pp. 173-174.

[13] Since 1992, U.S. GDP has increased 22 percent, while Japan's has increased by only 6 percent. See *The Economist*, January 11, 1997, p. 19.

Finally, the high-technology strategies of some Japanese companies and bureaucrats appear to be in disarray. Since the highly touted and effective Very Large Scale Integration collaborative research project of the late 1970s, there are no examples of Japanese technology policy initiatives that can be associated with subsequent gains by Japanese companies in international markets, while examples of expensive programs that have not met their stated goals are easy to cite, such as the Fifth Generation Computer project and some aspects of Japan's space program.[14] In November 1994 the Ministry of International Trade and Industry created a private-sector advisory panel to examine Japan's science and technology policies out of concern that current policies and programs will not be sufficient to ensure future Japanese competitiveness in high-technology industries. The resulting report of this group, which represents a significant cross-section of Japan's industrial and technological leadership, paints a sobering picture of Japanese innovation.[15] Japanese companies and the Japanese government are aggressively responding to these challenges, as will be described in more detail in other parts of the present report. Perhaps the most visible shift is Japan's new focus on strengthening fundamental science and engineering research through increased funding and changes in institutional structures.[16]

The atmosphere has changed in the United States as well. Growing confidence on the part of U.S. industry is generally tempered by continued awareness of the need for vigilance in meeting the growing demands of the global marketplace. Recent administrations have launched a number of initiatives aimed at improving U.S. capabilities to develop and commercialize technologies.[17] A 1995 report on critical technologies, contrary to similar reports of the early 1990s, does not name any technologies in which the United States is lagging behind Japan or even Europe.[18] Some experts have asserted that the bilateral trade deficit with Japan will decline over the long term, and the focus of U.S. trade policy appears to be shifting to the rapidly growing deficit with China and other Asian countries. The strengthened position of U.S.-based companies, Japan's economic problems of recent years, and a growing interest in economic opportunities and challenges of other Asian markets have all contributed to "Japan fatigue" and less attention to Japan issues among U.S. companies, U.S. political leadership, and the public at large.[19]

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[14] More material on the Fifth Generation program is presented in Chapter 2. Japan has two space programs. The National Space Development Agency (NASDA) manages such activities as the development and operation of launchers, participation in the international space station, and development of the Hope reentry vehicle. These activities are mainly funded by the Science and Technology Agency. Japan has sought to enter global markets in areas such as launching satellites but has realized only limited success thus far. NEC and other Japanese companies are already world leaders in the market for satellite ground stations. The Institute for Space and Astronautical Science (ISAS) is an interuniversity research program under the Ministry of Education, Science, and Culture. Much smaller than NASDA, ISAS focuses on space science and is seen as being very successful and cost effective.

[15] See Sangyo Kozo Shingikai Sogo Bukai Sangyo Gijutsu Shoiinkai (Industrial Structure Advisory Committee, Industrial Technology Subcommittee) and Sangyo Gijutsu Shingikai Sogo Bukai Kikaku Iinkai (Industrial Technology Advisory Committee, Planning Subcommittee), *Kagaku Gijutsu Sozo Rikkoku e no Michi o Kirihiraku Shiteki Shisan no Sozo, Katsuyo ni Mukete* (Clearing a Path Toward a Nation Based on Creative Science and Technology; Toward Creating and Utilizing Intellectual Assets), June 1995.

[16] Hidenao Nakagawa, Minister of State for Science and Technology, "Constructing a New Global Partnership—Science and Technology as an Investment for the Future," speech given at the U.S. National Academy of Sciences, Washington, D.C., August 8, 1996.

[17] These are discussed in Chapter 3.

[18] Office of Science and Technology Policy, *National Critical Technologies Report* (Washington, D.C.: U.S. Government Printing Office, 1995).

[19] Thomas L. Friedman, "Japan Fatigue," *The New York Times*, January 11, 1995, p. A21.

MAJOR ISSUES AND OUTLINE OF THIS STUDY

In preparing this report the Competitiveness Task Force focused on the links between the U.S.-Japan science and technology relationship and the most pressing priorities and concerns facing the U.S. economy. In considering the issues raised by debates over competitiveness in the 1980s and early 1990s and taking into account how conditions have changed, the task force is acutely aware that many U.S.-based companies and industries are responding to the challenge of global competition, some very effectively. Recognizing the ongoing debate among economists over the extent of recent productivity growth in the U.S. economy, the committee considers that the United States is doing at least as well on this front as other advanced industrial economies.[20]

Although concerns over the management and technology development capabilities of U.S. companies and the ability of the U.S. economy to produce advances in productivity have subsided to some extent, the questions first raised in the 1980s over whether the United States could create and maintain high-paying, stable employment in an increasingly competitive global economy have reasserted themselves. *The committee believes that this is the clearest challenge facing the United States—creating and maintaining an economy and enterprises that generate good jobs and a high standard of living over the long term by sustaining a well-funded and innovative science and technology base.*

What do science and technology relations with Japan have to do with maintaining high-value-added employment in the United States? The committee believes that both innovation and international relationships are linked to this broader concern. First, innovation is the most important factor in productivity growth, which is necessary for an economy to deliver growth in real incomes.[21] Second, innovation and technology development are increasingly global activities, and the United States is at the center of this globalization process.[22] Therefore, international scientific and technological relationships can be expected to have a significant impact on U.S. job creation and incomes. U.S. scientific and technological relations with Japan are worthy of particular focus because of Japan's status as a techno-industrial superpower, despite recent setbacks.

Also, the patterns and conflicts that have sometimes characterized the U.S.-Japan relationship may be repeated in science and technology relations with other countries focused on utilizing technology to sustain rapid economic development. U.S.-based manufacturing and service activities are increasingly dependent on overseas markets for future growth, but some companies are paying a high cost to access those markets, in terms of transferring production and technology. It is important that the lessons of past and current experiences with Japan be incorporated into public- and private-sector relations with other countries.

This report examines the U.S.-Japan relationship in science and technology with a view toward the larger economic developments the task force sees as desirable for the United States. The task force focused on two key sets of issues:

1. Are there structural features of the U.S.-Japan relationship that affect the ability of the United States to produce and utilize innovation? How has the relationship changed in the recent past, and what do current trends indicate about the prospects for the future?

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[20] Council on Competitiveness, *Competitiveness Index 1996: A Ten-Year Strategic Assessment* (Washington, D.C.: Council on Competitiveness, October 1996).

[21] See Council of Economic Advisers, *Supporting Research and Development to Promote Economic Growth: The Federal Government's Role*, October 1995.

[22] U.S. Department of Commerce, Office of Technology Policy, *Globalizing Industrial Research and Development*, Office of Technology Policy, 1995 and Center for Strategic and International Studies (CSIS), *Global Innovation/National Competitiveness* (Washington, D.C.: CSIS, 1996).

2. Are there lessons and insights to be drawn from the U.S. science and technology relationship with Japan with implications for how the United States—government, industry and research institutions—should approach international relationships in the future? How should the United States build science and technology links with key individual countries and regions, most importantly Japan but also including China and other emerging Asian economies? How should the United States approach such issues as multilateral harmonization of market and innovation systems in areas such as R&D subsidies, consortia, and intellectual property protection?

With its focus on the conditions necessary to maintain high wage employment for U.S. citizens, the committee is putting its emphasis on the interests of Americans in their role as producers. Superior research and development, and effective utilization by companies that maintain significant capabilities to innovate and manufacture in the United States, whether they are based in the United States, Japan or elsewhere, are the necessary conditions. The task force recognizes that Americans have an additional stake in U.S.-Japan science and technology relations as consumers, although this linkage is not a major focus of the report. U.S. citizens derive benefits from Japanese innovation when they purchase Japanese high-technology products. U.S. consumers also benefit from competition in high-technology markets, which expands consumer choices and lowers prices over time.

To chart a course for the future of the U.S.-Japan science and technology relationship that advances U.S. economic and competitiveness interests, it is necessary to understand Japanese and U.S. approaches to innovation; how these approaches have developed, particularly over the past four decades; and how U.S. and Japanese interactions in science and technology have been shaped by this historical context. Chapter 2 describes the institutional framework for innovation in Japan, including historical background. Chapter 3 provides similar background for the United States.

Chapter 4 reviews the statistical and policy context for U.S.-Japan science and technology relationships and competitive trends. Chapter 5 reviews information gathered by the committee on U.S.-Japan science and technology relationships and competitiveness trends in several key industries. Chapter 6 outlines the committee's approach to defining U.S. economic and competitiveness interests in science and technology relations with Japan and contains a discussion of key issues and policy options for the United States. Chapter 7 presents the committee's conclusions and recommendations.

2
Science, Technology, and Innovation in Japan

SUMMARY POINTS

• Scientific and technological relations between the United States and Japan have been extensive for over 100 years. The historically predominant pattern of interaction has involved a predominant flow of technology and expertise from the United States to Japan, mainly through industrial and business relationships but also through interactions involving government laboratories and universities.

• During the postwar period, Japan refined its government and private-sector approaches that had been developed earlier to lower the prices of and maximize the inflow and diffusion of foreign technologies. The government's control over trade and foreign direct investment allowed a coordinated industry-government approach to obtaining technology from foreign companies in exchange for limited market access and licensing fees.

• The acquisition, effective adaptation, and improvement of technologies from abroad by Japanese industry served as the basis for Japan's rapid economic growth and international competitiveness in a wide variety of manufacturing industries. The Japanese government's role in the acquisition and diffusion of technologies complemented the development of superior production and enterprise systems by Japanese industry.

• Asymmetrical market access—limited access by U.S. companies to the Japanese market juxtaposed with open access by Japanese companies to the U.S. market—had a long-term, negative impact on the competitiveness of several U.S. industries and the market positions of specific companies.

• But conditions are now changing. Japanese industry and government have less leverage to extract technology from foreign companies than they once did, and there is less scope for low-risk borrowing. Japan is renewing efforts to build greater domestic capabilities for generating fundamental innovations and new approaches to international cooperation.

THE DEVELOPMENT OF JAPANESE CAPABILITIES IN SCIENCE, TECHNOLOGY, AND INNOVATION

The key elements underlying Japan's industrial and technological rise have remained remarkably consistent over time. They include (1) central government policies that encourage the adoption and diffusion of foreign technologies through lowering private-sector risks, stimulating demand, and providing educational and other infrastructure; (2) a diffuse base of entrepreneurial vitality and a strong competitive private-sector that is receptive to new technologies and capable of improving them; and (3) a political and ideological climate that generally allows for consensus on national imperatives and flexibility in policy approaches to meeting them.

A number of the critical environmental factors that have favored Japanese industries during the postwar period have shifted over the past decade and a half. Other nations are seeking to build industrial and technological strength by utilizing approaches similar to Japan's, with some measure of success. Japanese government and industry continue to make adjustments aimed at increasing national capabilities to produce fundamental innovations and establishing new mechanisms for tapping foreign capabilities.

PRE-WORLD WAR II LEGACY

The foundation for Japan's assimilation of technologies from abroad for rapid industrialization was clearly present in 1853, when the West's challenge to the isolation policy of the Tokugawa shogunate appeared in the form of Commodore Perry's "black ships." Decentralized political power and economic competition between feudal domains led to the emergence of a large class of skilled crafts workers dispersed throughout the country and receptive to applying new innovations.[1] Further, Japan had developed a complex commercial economy prior to industrialization, including a national distribution system for marketing a wide variety of goods between numerous urban centers.[2] The national security crisis brought on by the black ships helped consolidate support for the importation of foreign technologies and industrialization to meet the Western challenge.[3]

Under the government of the Meiji Restoration, established in 1868, regional programs to import and assimilate foreign know-how were enhanced by national-level initiatives to promote the development of modern industries central to arms making and military capability through government investment and ownership.[4] Foreign experts were typically hired during the start-up phase and then dismissed when the necessary expertise had been absorbed by the Japanese. From the early 1880s, these companies were sold to entrepreneurs, with several developing into *zaibatsu* (industrial-financial groups), which played an important role in Japan's industrial and technological development. In addition to its direct role in launching enterprises, the central government established engineering faculties in the new imperial universities and other educational institutions to train engineers in the new techniques.

Japan's industrial and technological development accelerated through the early twentieth century. Extensive importation of foreign technologies continued, with important transfers occurring through the formation of joint ventures and other direct investments by foreign multinational corporations such as Western Electric, General Electric, and Ford Motor Company.[5] At the same time, the Japanese industrial sector was growing and evolving rapidly, with the spread of modern management and the emergence of large-scale corporations.[6] The *zaibatsu,* such as Mitsui and Mitsubishi, developed from an initial focus on nonmanufacturing industries into highly diversified conglomerates. Non-*zaibatsu* manufacturers, such as Hitachi, Takeda Chemical Industries, Kikkoman, and Ajinomoto, grew up in urban and rural areas. Partly

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[1] Tessa Morris-Suzuki, *The Technological Transformation of Japan: From the Seventeenth to the Twenty-First Century* (Cambridge, U.K.: Cambridge University Press, 1994), p. 54.

[2] W. Mark Fruin, *The Japanese Enterprise System: Competitive Strategies and Cooperative Structures* (Oxford, U.K.: Clarendon Press Oxford, 1992), p. 65.

[3] Richard J. Samuels, *Rich Nation, Strong Army: National Security and the Technological Transformation of Japan* (Ithaca, N.Y.: Cornell University Press, 1994), Chapter 2.

[4] Morris-Suzuki, op. cit., pp. 62-66, and Samuels, op. cit., Chapter 3.

[5] Mark Mason, *American Multinationals in Japan: The Political Economy of Japanese Capital Controls, 1899-1980* (Cambridge, Mass.: Harvard University Press, 1992), Chapter 1.

[6] Fruin, op. cit., pp. 76-77.

because of rapid economic growth, Japan's industrial development was marked by firm specialization, nonintegration of production and distribution, and extensive utilization of intercompany links, rather than by vertical integration in the pursuit of scope economies in production.[7] Along with the emergence of large companies, there remained considerable scope for technology-based entrepreneurial activity, supported by growing innovation networks built around industry associations; prefectural laboratories; technical colleges; and national technological institutions such as the Institute for Physical and Chemical Research (Riken), established in 1917.[8]

The growing availability of formally trained engineers was critical to the continued accumulation of technological capability and the process of enterprise development. The number of trained technicians employed by private enterprises grew from 700 in 1900 to 2,500 a decade later, and exceptional companies like Hitachi had begun to organize research divisions.[9] By the late 1920s, Japan possessed a considerable industrial and technological infrastructure. One Western observer rated the country as fourth in the world in the organization and scope of its research activities.[10]

Through the 1930s and during World War II, government involvement in the Japanese economy and innovation increased in such areas as economic planning and control, the formation of cartels, growing limitations on and eventually expulsion of foreign companies, and policies designed to encourage innovation. These developments left a mixed but mainly positive legacy for postwar innovation and economic growth. The bureaucratic industrial planning structure set up in the Ministry of Commerce and Industry (MCI) beginning in the late 1920s is the predecessor of the postwar Ministry of International Trade and Industry (MITI).[11] The expulsion of foreign capital prior to the war set the stage for strict controls over trade and foreign direct investment after the war. Industry and government gained experience in implementing collaborative technology development programs. The war itself forced Japan to accelerate the pace of investment in science and technology, as access to foreign technology was shut off.[12] This isolation meant that Japan fell considerably behind the technical levels of other advanced

[7] Ibid., Chapter 3.

[8] Although Riken was founded as a government-industry institution to perform advanced research, by the late 1920s it had begun a very successful effort to launch startup companies in Japan, Manchuria, and Korea to commercialize its innovations. Morris-Suzuki, op. cit., pp. 126-129.

[9] Morris-Suzuki, op. cit., p. 108. Hitachi also tended to rely more on reverse engineering and scanning foreign technical literature than companies with formal links to foreign multinational companies and therefore developed more extensive operations for these activities earlier than its rivals.

[10] Maurice Holland, "From Kimono to Overalls: The Industrial Transition in Japan," *The Atlantic Monthly*, October 1928.

[11] There is debate over how much influence MCI/MITI has had. The issue will be taken up again in the next section and other parts of the report. Chalmers Johnson, in *MITI and the Japanese Miracle: The Growth of Industrial Policy, 1925-1975* (Stanford, Calif.: Stanford University Press, 1982), argues that the government apparatus has wielded considerable power as the headquarters for Japan's "developmental state." Others, including David Friedman, in *The Misunderstood Miracle: Industrial Development and Political Change in Japan* (Ithaca, N.Y.: Cornell University Press, 1988), assert that the government bureaucracy has always been more or less co-opted by industry and that, while government initiatives have often led to unanticipated positive results, government has been ineffective in achieving its stated goals. See also Daniel Okimoto, *Between MITI and the Market: Japanese Industrial Policy for High Technology* (Stanford, Calif.: Stanford University Press, 1989), and Richard Samuels, *The Business of the Japanese State: Energy Markets in Comparative and Historical Perspective* (Ithaca, N.Y.: Cornell University Press, 1987).

[12] Japan's German allies proved much more reluctant to transfer technology to Japan than the U.S. MNCs that were being expelled during the 1930s. See Morris-Suzuki, op. cit., p. 145.

countries during the war, but it led to larger-scale R&D efforts on the part of industry and a large jump in the proportion of young people receiving technical training.[13]

Nearly all the political-economic factors underlying Japan's industrial and technological ascendancy in the postwar period were in place when the war began, most notably: (1) government policies (often shaped by industry) that encouraged innovation through procurement, support for technology development, creation of a favorable environment for the importation of foreign technology and the provision of infrastructure for technical human resource development; (2) a technologically savvy industrial sector largely focused on serving smaller-scale, specialized demands rather than mass markets, and implementing flexible innovation and manufacturing strategies through focal factories and extensive utilization of subcontracting and corporate networks; and (3) a set of "bridging" public-private institutions (such as Riken, industry associations, and extension services for small- and medium-sized firms) that helped to diffuse technology and other forms of knowledge. Although Japan's ascendancy was not based on defense technology as such, these public and private approaches were shaped by an overarching focus on national security.

SCIENCE, TECHNOLOGY, AND THE POSTWAR MIRACLE

A Favorable International Environment: The U.S. Occupation and Alliance

The U.S. occupation and its aftermath ushered in several important changes with mainly positive impacts on Japanese innovation and industrial development. [14] Several U.S. occupation policies had a major long-term effect. Early on, initiatives such as land reform, the breakup of the *zaibatsu,* the expansion of educational opportunities, and the promulgation of a new constitution facilitated movement toward greater democratization and egalitarian income distribution. With the "reverse course" in occupation policy brought on by the onset of the Cold War, and the new imperative to encourage Japan's emergence as a U.S. strategic ally in Asia, the United States began to take active measures to promote reconstruction of Japan's industrial capability. These measures included "special vehicle procurement" by the U.S. military during the Korean War, which jump started the Japanese auto industry, and efforts to spread U.S. management and manufacturing techniques to Japanese industry through study missions. Many of Japan's engineering and technological capabilities that had been focused on the war effort were now diverted to commercial industries.[15]

The U.S.-Japan alliance also served as the foundation for a favorable international environment for Japan's industrial rise. Not needing a large military establishment, Japan has

[13] This was due to generous funding and the exemption of science students from military duties that was maintained until the last stages of the war.

[14] Perhaps the main difficulty in "explaining" Japan's economic and technological success is overdetermination—Japan had so much going for it that it is nearly impossible to isolate one or another dependent variable as being decisive. This point is made regarding the high-growth Asian economies in general by the World Bank in *The East Asian Miracle: Economic Growth and Public Policy* (New York: Oxford University Press, 1993), p. 6. This account is necessarily selective and focuses on technology.

[15] See Nihon Gakujutsu Shinkokai, Sentan Gijutsu to Kokusai Kankyo Dai 149 Iinkai (Japan Society for the Promotion of Science (JSPS), Committee 149 on Advanced Technology and the International Environment), *Gunji gijutsu kara minsei gijutsu e no tenkan (Conversion of military to civilian technologies)* (Tokyo: JSPS, 1994). The founders of Sony began their engineering careers performing research at the Imperial Naval Air Arsenal. See Samuels, op. cit., p. 50.

concentrated its resources on commercial industries and technologies.[16] The open international trading environment, characterized by gradual liberalization over the postwar period, is largely a result of U.S. initiative and leadership. Because of relatively free access to global markets, Japan has been able to invest at an internationally competitive scale in several industries—such as steel—where Japanese companies had been held back before the war.[17]

Of course, the generally favorable environment for trade and economic growth of the postwar period was not an advantage enjoyed uniquely by Japan. Several additional factors allowed Japan to take better advantage of this environment than other large economies.

Government Role in Facilitating the Importation and Diffusion of Critical Technologies

A unifying thread in Japan's postwar industrial success stories has been the effective utilization and improvement of technology acquired from abroad. Although Japan is now generally acknowledged to be a techno-industrial superpower, none of the most significant "hard" technologies on which this achievement is based were originally developed in Japan, notwithstanding Japan's formidable accomplishments in incremental improvements, commercialization, and developing new markets for imported technologies, as described below. The most important Japanese innovations have come in such areas as management and systems techniques. These "soft" technologies are embodied in the Toyota Production System and are comparable to the management innovations associated with mass production that the United States pioneered in the late nineteenth and early twentieth centuries.[18]

The shipbuilding industry was an early postwar success story for Japan, which had developed impressive capabilities prior to the war. Shipbuilding was one of the industries initially targeted by the Japanese government for preferential treatment in the form of access to scarce foreign exchange and low-interest policy financing.[19] Advanced structural welding and "block" construction techniques—key process technologies—were acquired when the Japanese government allowed the U.S. shipbuilder National Bulk Carrier Company to temporarily use the former Japanese navy yard at Kure in return for unrestricted access to manufacturing technologies by Japanese shipbuilders.[20] Building on these foreign techniques, the Japanese shipbuilding industry launched a series of collaborative research projects and developed further innovations. With this solid technological base, Japanese companies were able to take advantage of a favorable domestic and international market environment and by 1965 were producing 65 percent of the world's shipping tonnage.[21]

The Japanese government played a key role in brokering industry access to fundamental foreign technologies at favorable prices during the 1950s and 1960s. In the case of the steel

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[16] According to one estimate, between 1981 and 1994 the United States spent $3.5 trillion on defense, or $14,000 per capita, while Japan spent $2,500 per capita. See Ernest J. Oppenheimer, "The War Against Ourselves: Unequal Defense Costs Are the Villain in U.S.-Japan Trade Saga," *Barron's*, May 29, 1995, p. 43.

[17] During the early postwar period, Japan also reasserted itself in industries that had been globally competitive before the war, such as textiles.

[18] It is important to keep in mind that a great deal about Japanese innovation is not yet well understood. See Leonard H. Lynn, "Japan's Systems of Innovation: A Framework for Theory-Guided Research," *Research in International Business and International Relations*, vol. 6, 1994.

[19] Perhaps more important, the shipbuilders' customers were one of the primary targets of preferential government financing. See Kent E. Calder, *Strategic Capitalism: Private Business and Public Purpose in Japan's Industrial Finance* (Princeton, N.J.: Princeton University Press, 1993), p. 106.

[20] Morris-Suzuki, op. cit., pp. 187-189.

[21] Ibid.

industry, the basic oxygen furnace, developed in Austria in the early 1950s, was much more rapidly incorporated in Japan than in the United States, even allowing for the more rapid buildup in Japan's capacity.[22] As was the case in the shipbuilding industry, the process of importing and improving this critical technology was characterized by an active government role in organizing the importation process and negotiating favorable licensing arrangements. R&D collaboration between companies in developing complementary technologies, active promotion by industry associations, and fierce competition between firms in implementation improved efficiency and speeded adoption of the technology. In both steel and shipbuilding Japan dispelled the notion that possession of raw materials is a prerequisite to leadership in finished goods.

In contrast to shipbuilding and steel, where foreign innovators were more or less willing to license their know-how, computers and microelectronics are important examples of industries in which Japan confronted multinational corporations desiring access to the Japanese market. In these cases the government's leverage came from the Foreign Exchange and Foreign Trade Control Law of 1949 and the Foreign Investment Law of 1950. The latter provided the framework for government approval of foreign direct investments as well as technology agreements lasting for more than one year. [23] The formal requests for permission for direct investments or technology imports were submitted to the Ministry of Finance, which referred them to the agency with jurisdiction over the industry or technology—almost always MITI and often one or more additional economic ministries—for review.

The experiences of U.S. companies that sought to gain access to the Japanese market through exports or direct investment during the 1950-1980 time frame illustrate how Japanese industry and government worked together to gain access to foreign technologies while limiting access to the Japanese market.[24] IBM, Texas Instruments, and a few other companies with very strong patent positions were able to negotiate restricted access to the Japanese market through wholly owned subsidiaries after protracted negotiations, conditional on widespread licensing of their basic technologies to Japanese competitors. Companies in an intermediate position, such as Du Pont, were able to access the market but were steered into joint ventures that involved technology transfers to Japanese partners and often left control of critical customer interfaces with those partners. Companies in a weaker position, like Fairchild, were left with licensing their technology as the only viable option.[25]

Beginning in the late 1960s, Japanese restrictions on foreign investment and foreign exchange were gradually liberalized. Although informal market and investment barriers still impede foreign access to some of Japan's high-technology markets, the government's direct role in acquiring and diffusing foreign technology has declined. Yet the importance of this mediation in accumulating the technological foundation for Japan's growth is clear. Some point to the delay experienced by Sony when it sought permission from MITI to license the transistor from Western Electric in the early 1950s as a counterexample to show that the Japanese government's role was not always favorable to innovation. Closer examination reveals, however, that the actual delay

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[22] Leonard H. Lynn, *How Japan Innovates: A Comparison with the U.S. in the Case of Oxygen Steelmaking* (Boulder, Colo.: Westview Press, 1982).

[23] Leonard H. Lynn, "MITI's Successes and Failures in Controlling Japan's Technology Imports," *Hitotsubashi Journal of Commerce and Management,* December, 1994.

[24] See Mark Mason, *American Multinationals in Japan: The Political Economy of Japanese Capital Controls, 1899-1980* (Cambridge, Mass.: Harvard University Press, 1992), particularly Chapters 4 and 5, and Marie Anchordoguy, *Computers Inc.: Japan's Challenge to IBM* (Cambridge, Mass.: Harvard University Press, 1989).

[25] Fairchild licensed Japanese rights to the planar process—a fundamental semiconductor manufacturing technology—to NEC, which in turn licensed the know-how to other Japanese companies. See Mason, op. cit., pp. 195-197.

was just a few months, during which Sony had an internal team working on the technology.[26] As is the case for a number of the examples of failed or counterproductive industrial policy during the high-speed growth period, Sony's transistor licensing experience shows that the influence of the Japanese government on all aspects of Japan's industrial development, while considerable, was not rigid enough to impede companies with good ideas and the energy to pursue them. Indeed, industrial policy was often formulated or co-opted by industry.[27] The transistor case also illustrates another key feature of Japanese innovation: creativity by industry in the application and modification of basic technologies imported from abroad.

U.S.-Japan cooperation in defense production and defense technology has also contributed to the capabilities of Japanese companies, particularly in the aircraft industry.[28] Licensed production of U.S.-developed aircraft has represented an important business base for the aerospace divisions of Japan's heavy-industry firms, and the basic technologies for several specific commercial products in which Japanese companies hold global leadership were originally transferred in military programs. Ishikawajima-Harima Heavy Industries, particularly its success in producing long shafts for commercial jet engines, is one example.

Industry Creativity in Applying and Modifying Foreign Technologies

As is well known, Sony first utilized the transistor to make small radios, an application that had not been pursued by American inventors. This is by no means an isolated case—developing new applications and markets for imported technologies, modifying technologies for new applications, and rapidly moving forward with complementary innovations have been hallmarks of the companies in most of Japan's internationally competitive industries. At the aggregate level, a late 1980s study showed that Japanese firms tend to develop and introduce new products and processes based on external technology more quickly and economically than U.S. companies do.[29]

Starting with the transistor, several examples can be drawn from consumer electronics. In the late 1950s the importation of new commercial video recorders by Japanese government broadcaster NHK from U.S. inventor Ampex alerted MITI and led to a systematic effort to import the basic technology.[30] Several years later Sony developed a much smaller machine that could be used to show movies in commercial jet aircraft, and in 1969 it introduced the U-Matic, which reached a large industrial market.[31] Sony and Matsushita later developed video cassette recorders for home use, the Matsushita standard eventually winning out to achieve enormous commercial success around the world.

Japanese companies have continued to rapidly introduce new electronics technologies into consumer electronics products. For example, the first microprocessor was developed by Intel in 1969 in response to the request of Busicom, a Japanese calculator maker.[32] Flat panel displays

[26] Lynn, op. cit., pp. 27-30.

[27] This is one of Friedman's main points.

[28] Many of the developments in this industry are more recent, although cooperation dates back many years. Samuels, *Rich Nation, Strong Army*, op. cit., and National Research Council, *Maximizing U.S. Interests in Science and Technology Relations with Japan: Report of the Defense Task Force* (Washington, D.C.: National Academy Press, 1995).

[29] Edwin Mansfield, "Industrial Innovation in Japan and the United States," *Science*, September 30, 1988, pp. 1769-1774.

[30] Morris-Suzuki, op. cit., p. 195.

[31] Morita, op. cit., p. 111.

[32] Initially believing that the new invention had little application apart from calculators, Intel gave Busicom a monopoly on the original microprocessor—the 4004—in return for the Japanese company's agreement to pay for the

utilizing liquid crystals were first developed by U.S. companies in the 1960s, which conceived of the technology as a possible long-term replacement for cathode ray tubes, but did not persist in developing it to the point where it could be incorporated into marketable products. In contrast, Sharp Corporation introduced liquid crystal displays (LCDs) into its calculators in the early 1970s. Sharp continued to improve and develop LCDs as it diversified into other product lines, establishing a leading position in the technology that has continued to the present.[33] Consumer electronics markets that Japanese companies either pioneered or took from U.S. rivals have been a powerful vehicle for the development and refinement of new electronics component technologies.[34]

A prominent nonelectronics example is the machine tool industry. Japan's success in this industry has been largely due to the utilization of numerical control (NC) technology in small, general-purpose tools.[35] In the United States, where NC technology was developed at the Massachusetts Institute of Technology with U.S. Department of Defense funding, industry mainly applied the advances to high-end applications—the potential market for general-purpose NC tools was not appreciated. As a result of their success in developing general purpose NC machine tools for smaller Japanese manufacturers, Japanese toolmakers achieved great export success in the 1970s and 1980s.

Japanese industrial organization practices have encouraged the creative adaptation of technology. Even as greater opportunities to pursue mass markets grew during postwar economic growth, Japanese industries generally did not pursue vertical integration and rigid production and management systems. Rather, interfirm networks of various types have proliferated and evolved. The business and technology focus of even the largest Japanese firms remained with product-centered factories integrating the activities of numerous subsidiaries and suppliers.[36]

Another aspect of Japan's capability to innovate has been the relative success of large Japanese companies in diversifying into new technologies and businesses. This has been particularly true in the electronics industry. The relative disaggregation of Japanese companies like Hitachi and Matsushita—where the main company focuses on technology development, final assembly in core businesses, and corporate staff functions, while distribution, components manufacture, and peripheral businesses are spun off to subsidiaries—may be partly responsible for this flexibility. The human resource policies of Japanese companies have served to reinforce and perpetuate this disaggregation. With emphasis on entry-level hiring over mid-career hiring, lifetime employment, and wage differentials determined largely by seniority, rewards in large, prestigious Japanese companies are standardized across functions, providing a strong incentive to spin off noncore activities to subsidiaries with lower salary structures.[37] This standardization of rewards encourages other management practices associated with superior product development

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entire cost of development. Several years later Intel was able to buy back the rights when Busicom ran into difficulties. See Gordon Moore, "Intel Chief Recalls Japanese Connection in Development of Microprocessors," *Nikkei Weekly,* May 8, 1995, p. 4.

[33] U.S. Department of Defense, *Building U.S. Capabilities in Flat Panel Displays: Report of the Flat Panel Display Task Force,* September 30, 1994, pp. VI-18-VI-19.

[34] Photographic equipment is another startling example. Japanese companies were the first to replace mechanical components with electronic ones and quickly captured a major share of the global market from German and U.S. companies.

[35] Friedman, op. cit.

[36] See Fruin's discussions of Toshiba and Toyota, op. cit., Chapters 6 and 7. Also see Ken-ichi Imai, "Japan's Corporate Networks," in Shumpei Kumon and Henry Rosovsky, eds., *The Political Economy of Japan Volume 3: Cultural and Social Dynamics* (Stanford, Calif.: Stanford University Press, 1993).

[37] D. Eleanor Westney, "The Evolution of Japan's Industrial Research and Development," in Masahiko Aoki and Ronald Dore, eds., *The Japanese Firm: The Sources of Competitive Strength* (New York: Oxford University Press, 1994), p. 172.

performance, such as movement of technical personnel between research, product development, and manufacturing.[38] This flexibility in human resource utilization also allows for movement between divisions, such as movement between commercial and military aircraft production.

Infrastructure for the Development of Technology-Based Industries

Several additional factors have contributed to Japan's industrial and technological development. The first is the rapid expansion of higher educational opportunities in Japan over the postwar period. Engineering education has been a major focus—today Japanese and American institutions award a similar number of engineering bachelor's degrees, despite the fact that the United States awards many more degrees overall and has twice Japan's population.[39]

Other aspects of government industrial and technology policy are more difficult to evaluate in a general way. Policies toward industrial finance, regulation, market development, and technology development have had a significant impact on several specific industries at particular times.

.The contribution of Japanese trade policy to the development of the auto industry is one example. Although the Japanese auto industry did not receive direct government assistance on the scale of some other manufacturing sectors, imports were restricted through the use of quantitative limits and high tariffs.[40] This discouraged foreign manufacturers from entering the Japanese market and allowed the Japanese auto industry to develop its manufacturing and technological capabilities in a protected domestic market. The semiconductor industry provides another example of a Japanese industry that was able to accumulate experience and raise productivity under the umbrella of trade protection.[41]

Export promotion has played a role as well. Japan's general trading companies predated World War II and provided an important institutional foundation for Japan's exports, particularly during the period before Japanese manufacturers had become large enough to establish their own distribution channels overseas. The MITI-affiliated Japan External Trade Organization (JETRO) is widely regarded as a highly effective conduit of market and other information to Japanese businesses. There are no U.S. institutions comparable to the trading companies or JETRO. Although some critics have focused on the utilization of predatory dumping strategies by Japanese manufacturers, these have had a major impact in only a few specific cases, most notably the domestic price maintenance cartel organized by Japanese television manufacturers in the 1960s and the MITI-financed export of machine tools in the early 1980s.[42] As noted above, the key developments that led to Japanese ascendancy in those industries had occurred earlier over a

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[38] D. Eleanor Westney and Kiyonori Sakakibara, "The Organization and Careers of Engineers in the Computer Industry in Japan and the United States," Massachusetts Institute of Technology Working Paper, 1985. Another possible factor contributing to effective innovation strategies is the often-heard claim that Japanese CEOs and other top managers are more likely to have technical backgrounds than their U.S. counterparts. See, for example, Hiroyuki Odagiri and Akira Goto, "The Japanese System of Innovation: Past, Present and Future," in Richard R. Nelson, ed., *National Innovation Systems: A Comparative Analysis* (New York: Oxford University Press, 1993).

[39] National Science Board, *Science and Engineering Indicators-1993* (Washington, D.C.: U.S. Government Printing Office, 1993). If one compares the combined number of natural science and engineering bachelor's degrees, this seeming "gap" is less pronounced.

[40] Odagiri and Goto, op. cit., p. 100.

[41] Laura D'Andrea Tyson, *Who's Bashing Whom? Trade Conflict in High-Technology Industries* (Washington, D.C.: Institute for International Economics, 1992), Chapter 4.

[42] Clyde V. Prestowitz, Jr., *Trading Places: How America Allowed Japan to Take the Lead* (Tokyo: Charles E. Tuttle, 1988), pp. 203 and 223. Dumping has also been implicated in Japanese gains in semiconductors, motorcycles, textiles, and photographic film.

considerable period, although the loss of U.S. competitiveness became apparent over a short time span because of the flood of Japanese imports.

Industrial policy measures to develop domestic markets, mainly financing incentives for customers of emerging industries, were also important to several industries. For example, large amounts of policy finance directed to merchant shipping companies allowed them to increase purchases from Japan's shipbuilders. The MITI-financed Japan Electronic Computer Corporation, which purchased and leased Japanese computers to domestic users, was a key factor in the growth of Japan's computer industry during the 1960s and 1970s.[43] A financing program intended by MITI to encourage consolidation of small manufacturers was co-opted at the local level and mainly used to purchase sophisticated machine tools.[44]

Technology development programs also have had a positive impact in a few specific industries.[45] Unlike the United States, where a number of technologies underlying major industries have been developed with government funding, Japanese government funding has not yet yielded significant breakthroughs. However, most analysts agree that the extensive network of national laboratories, local and regional institutions for manufacturing and technology extension, and government-sponsored R&D consortia have played a positive, but mainly supportive, role in Japanese innovation.

Japan's government-supported R&D consortia have attracted the most attention from abroad and have spurred a certain degree of imitation in the United States.[46] In the 1960s the Japanese government established a special funding program to support industrial consortia. During the 1970s and 1980s, overall funding and the number of consortia increased, the most important being those targeting semiconductors and computers. Japan's early computer consortia were aimed at catching up with the innovations developed by IBM in the 1960s, and some observers credit them with supplementing corporate efforts to prevent falling irretrievably far behind. The Very Large Scale Integration program of the late 1970s is often given credit for enhancing Japan's competitive prospects in semiconductors and semiconductor equipment, since the end of the project coincided with a market share surge by Japanese companies. In addition to helping device makers and equipment manufacturers gain familiarity with the latest chipmaking manufacturing technologies, providing a base for their subsequent advances, the VLSI project and other consortia have encouraged the formation of information networks among researchers, helped companies maintain R&D funding oriented toward long-term goals, and delivered other benefits apart from actual research results.[47]

RECENT CHANGES AND CURRENT CHALLENGES

Over the past 15 years or so, a number of changes have occurred in the environment for Japanese government and industry strategy building toward technology and industrial development. One example is the gradual lowering of formal trade and investment barriers that occurred during the 1970s. As a result, the Japanese government's direct role in facilitating

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[43] Anchordoguy, op. cit.

[44] Friedman, op. cit., p. 167.

[45] Okimoto, op. cit., and David Cheney, "Japan's Technology Policy: What's the Secret?" (Washington, D.C.: Council on Competitiveness, 1991).

[46] Gerald J. Hane, "The Real Lessons of Japanese Research Consortia," *Issues in Science and Technology*, Winter 1993-94, pp. 56-63, and National Research Council, *R&D Consortia and U.S.-Japan Collaboration: Report of a Workshop* (Washington, D.C.: National Academy Press, 1991).

[47] One issue on which there is some disagreement is the extent to which Japanese consortia have involved fundamental research and the trends.

technology access and diffusion has been greatly diminished. The aircraft industry is one important exception to this general trend.[48]

In addition, as a natural consequence of success, by 1980 Japanese industry had reached the technical frontier in a number of manufacturing industries, decreasing the scope for continued low-risk borrowing from abroad. The upward valuation of the yen during the late 1980s and the early 1990s also had an impact on Japan's competitive advantage, especially for industries that were labor or energy intensive or that relied heavily on exports or domestically produced basic materials. Finally, the costs of overprotection of domestic industries and restrictions on new entry are increasingly apparent, particularly in the wake of the "bubble economy."

The response by Japanese government and industry to these changes in the science and technology area has involved two main thrusts. The first has involved efforts to improve Japan's level of basic scientific and engineering research, with a focus on particular fields with perceived potential for wide commercial application. The second thrust has been the development of new mechanisms for tapping foreign science and technology more appropriate to the changed environment, such as overseas R&D laboratories and international R&D programs funded by the Japanese government. At this time it is difficult to say whether these changes have made a great difference in the way Japan innovates.

Efforts to Improve Fundamental Research Capabilities

A number of MITI reports from the late 1970s and early 1980s emphasized the importance of increasing Japan's capability to develop original technology and introduced concepts such as *gijutsu rikkoku* (technology nation building or techno-nationalism) and the "advanced information society."[49] MITI launched a series of new programs to fund research in areas relevant to industry. In 1981 the Next Generation Basic Technology project was established as a new funding pool for industrial consortia. The project selected microelectronics, new materials, and biotechnology as technical focus areas for collaborative R&D by teams of industry, government, and university researchers. By the mid-1980s the program was scaled back somewhat due to budget concerns and the reluctance of companies to participate in many of the projects.[50]

Also announced in 1981 was the Fifth Generation Computer Project, a 10-year program of advanced computing research with a budget of $450 million. Although the ambitious project raised concerns in the United States that Japan would leapfrog ahead in computer technology, the technical goals were later scaled back, and by the time the program was completed in 1992 its sponsors were emphasizing the training of young researchers and other intangibles as the most important benefits, since no commercially significant technologies emerged.[51] Another MITI initiative started during the same period is the Technopolis project, which involves targeted tax

[48] See Samuels, op. cit., and National Research Council, *High-Stakes Aviation,* op. cit.

[49] Morris-Suzuki, op. cit., pp. 209-219. Translating *gijutsu rikkoku* as "techno-nationalism" is controversial, as noted here and by Samuels, op. cit., p. 48.

[50] Morris-Suzuki, op. cit., p. 214. More recently, MITI's consortia funding mechanisms and the Agency for Industrial Science and Technology laboratories were reorganized in 1993.

[51] For a discussion of the training benefits of Japanese consortia, see Hane, op. cit. One of the early assessments that predicted great success for the program was that of Edward Feigenbaum and Pamela McCorduck in *The Fifth Generation: Artificial Intelligence and Japan's Computer Challenge to the World* (Reading, Mass.: Addison-Wesley, 1983).

breaks and infrastructure building for high-technology manufacturing and R&D in designated cities throughout Japan. Here, too, the results appear to be less than spectacular.[52]

Another round of MITI initiatives began in the mid-1980s, including the Key Technology Center, a funding program for industrial technology consortia and telecommunications demonstration projects run jointly by MITI and Ministry of Posts and Telecommunications, utilizing proceeds from the sale of Nippon Telephone and Telegraph stock to the public. Typically, a research organization is formed to oversee the work, with 70 percent of the funding provided by the Key Technology Center and the other 30 percent by participating companies. A number of the projects appear to be linked to larger industrial and competitiveness goals for the industry involved.[53] The Japanese government is reportedly launching a review of the Center's activities, following public criticism of the program's effectiveness.[54] Besides MITI, several other agencies launched R&D support programs to encourage higher levels of fundamental research and intersectoral collaboration, including the ERATO (Exploratory Research for Advanced Technology) program of the Science and Technology Agency. The *kakenhi* system for industry-university collaboration was established earlier by the Ministry of Education, Science, and Culture but attracted increasing participation in the late 1980s.

Despite a number of initiatives by several agencies to encourage more fundamental research, what had conspicuously not emerged in Japan until recently was a commitment to substantially increase funding for basic science and engineering research and to implement structural changes at Japanese universities. Much more conspicuous than developments in universities has been the growth of Japan's national technology projects in space (the H-II rocket), energy (development of fast breeder reactors), and defense (the FS-X).

With the Basic Law on Science and Technology passed by the Diet in 1995 and the Science and Technology Basic Plan released in July 1996 (see Box 2-1), it appears that improvement of fundamental research capabilities has moved to the forefront as a major national priority in Japan. Although a number of excellent Japanese university researchers and groups are pursuing cutting-edge research, the primary university role in Japanese innovation has until now been education at the undergraduate and master's levels. In addition to a major increase in funding for basic research, the plan seeks to address structural impediments to invigorating Japanese research.

Changes also have occurred in Japanese industrial R&D. Corporate R&D investments grew rapidly from 1979 through the early 1990s.[55] A number of large Japanese companies, led by the electronics giants, such as Hitachi, NEC, and Toshiba, established "fundamental" research labs during the mid- and late 1980s. There are indications that Japanese companies tried to protect their fundamental research efforts as they cut back on overall R&D spending during the recent post-bubble recession.[56] Still, despite visible efforts to build research organizations with greater

[52] Morris-Suzuki, op. cit., p. 226, reports that few of the designated regions had reached goals for high-technology job creation. Tsukuba Science City had been established much earlier and only began to attract a critical mass of industrial labs in the mid- to late 1980s. Another hotbed of high-technology activity—the Atsugi area in Kanagawa Prefecture, west of Tokyo—emerged without the designation.

[53] See discussion of aircraft-related Key Technology Center projects in Samuels, op. cit., p. 282. The research results of 14 of the projects launched between 1986 and 1991 are reported by the Japan Key Technology Center in *Research Results of Investment Projects* (Tokyo, 1996).

[54] See Asako Saegusa, "Japanese technology fund faces ministry criticism," *Nature,* April 3, 1997. This criticism has reportedly emerged from the Ministry of Finance. Critics point out that over $1.5 billion has been spent on the program since 1985, but that only $10 million or so in royalties have been collected on technologies developed through the program. The article speculates that this criticism may be part of a backlash against the large increases in science and technology funding currently planned.

[55] Westney, op. cit., p. 154.

[56] See "Science in Japan," *Science*, November 18, 1994, p. 1170.

Box 2-1 Japan's Science and Technology Basic Law and Basic Plan

With passage of the Science and Technology Basic Law by the Diet in 1995, Japan established a new framework for development of its science and technology policies. The Basic Law states that Japan will promote diversified R&D in a balanced way, secure and train researchers and technicians, improve research facilities, promote information intensive research, and promote R&D exchanges.[1] The Basic Law also provides for the formulation of a Science and Technology Basic Plan by the government through consultation with the Prime Minster's Council for Science and Technology.

The Science and Technology Basic Plan was announced in 1996. The Basic Plan states that Japan should take the initiative in advancing the frontiers of science and technology. The Basic Plan also notes that Japanese science and technology have been in an "uneasy situation" in recent years, due to declining investment in R&D, a continued low percentage of R&D funded by government relative to other advanced countries, and declining flexibility and competitiveness in Japan's R&D system.[2] The plan provides a guiding framework for policies and programs during the 1996-2000 fiscal years.

The Basic Plan outlines a number of specific budget and structural goals aimed at improving the environment for fundamental research in Japan. One goal is to increase the number of post-doctoral researchers to 10,000 by 2000 from about 6,000 as part of efforts to encourage greater mobility between institutions. Another is to increase the ratio of research support personnel to researcher to 1:1 at national research institutes and to 1:2 at universities as soon as possible. The Basic Plan also calls for the introduction of systems for impartial evaluation of projects and institutions in government and universities, and increased use of competitive funding mechanisms. The Basic Plan's most well known goal is to increase government R&D spending over the 1996-2000 fiscal years by 50 percent to 17 trillion yen compared with the previous five years.

The Basic Plan also sets out an ambitious agenda for international cooperation. Post-doctoral fellowships for foreign researchers supported by the Japan Society for the Promotion of Science and the Science and Technology Agency (STA) are expected to more than double to 1,050 and 1,000, respectively, by 2000. The Basic Plan also seeks to open Japan's universities and research institutions to foreign researchers. As of 1993, there were only 25 tenured foreign professors in Japan's 100 national universities.[3]

Several new multi-agency research programs have been launched along with the Basic Plan. One example is the Brain Science Research program, which involves STA; the Ministry of Health and Welfare; the Ministry of Agriculture, Forestry and Fisheries; the Ministry of International Trade and Industry; and the Ministry of Posts and Telecommunications. The program is budgeted at almost 15 billion yen (about $135 million) for fiscal year 1997.

Both foreign and Japanese observers note that effective implementation of the Basic Plan involves many long-term challenges and major changes in Japan's R&D culture. As a comprehensive outline of broad national goals and the barriers that need to be overcome, the Basic Plan represents an impressive agenda.

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[1] "Outline of the Science and Technology Basic Law," Law 130 of 1995, English translation, 1995.
[2] Government of Japan, *Basic Plan for Science and Technology*, English translation, July 2, 1996.
[3] Andrew Pollack, "Japan is Planning Vast Increase in Science Research Budget," *New York Times*, July 2, 1996.

capability for achieving breakthrough innovations, to date it has been difficult for Japanese industry to modify traditional patterns of research and innovation.[57]

New Mechanisms for International Cooperation and Foreign Technology Acquisition

The focus for Japan's activities in science and technology cooperation and technology acquisition has remained the United States. The Japanese government, mainly MITI, launched a number of R&D programs starting in the mid-1980s in which foreign participation was sought (see Box 2-2). For example, several of the Key Technology Center projects invited participation by foreign multinational companies, including IBM's membership in the International Fuzzy Engineering Research Lab.[58] The Human Frontier Science Program (HFSP), a joint MITI-Science and Technology Agency effort to fund international teams doing basic research in life sciences, was first proposed by Prime Minister Nakasone in 1987, and a significantly scaled back version of the plan has been operating for a number of years. The Supersonic/Hypersonic Technology Program was launched in 1989 as a $200 million, eight-year project to develop a scale prototype turbo-ramjet, Mach 5, methane-fueled engine.[59] Participation by the world's leading jet engine companies is an integral aspect of the program, which aims to position Japanese jet engine makers for participation in a future international effort to develop an engine for the next generation supersonic transport.[60]

Starting with the Intelligent Manufacturing Systems (IMS) program in 1989, MITI proposed several large-scale initiatives for collaborative R&D involving foreign companies and universities in fields with large commercial potential. The original IMS proposal, in which MITI and Japanese companies would have linked directly with U.S. companies and universities in research on advanced manufacturing, was derailed by U.S. concerns that it would result in Japanese commercialization of U.S.-developed fundamental technologies. The U.S. government brought the program development effort under the U.S.-Japan Science and Technology Agreement and brought other countries into the process. After protracted government-to-government negotiations, a two-year feasibility study involving Japan, the United States, and other regions was undertaken, and a framework for continued cooperation was ratified in 1995.[61]

Following on the heels of IMS were the Real World Computing, Micromachine, and Atomic Manipulation collaborative R&D programs. In one sense, the Real World Computing program is the successor to the Fifth Generation Computing project, with a focus on parallel processing and optical computing technologies. Following an initial effort to directly involve U.S. universities in a major role and U.S. government resistance similar to what occurred with IMS, MITI revamped its plans for foreign participation. A joint prototyping service for optoelectronic devices and

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[57] This is not to say that they will not do well using or modifying those traditional patterns.

[58] National Research Council, *R&D Consortia and U.S.-Japan Collaboration*, op. cit., p. 15.

[59] Testing of several components of the engine has been ongoing, and development of other components is being completed. The current plan is to complete testing of the demonstration engine in 1998 (communication from GE Aircraft Engines, March 1997).

[60] Foreign companies receive 25 percent of the funding, with Japanese participants Ishikawajima-Harima Heavy Industries, Mitsubishi Heavy Industries, and Kawasaki Heavy Industries splitting the remaining 75 percent. The foreign participants are the Pratt & Whitney division of United Technologies and GE Aircraft Engines of the United States, Rolls Royce from the United Kingdom, and Snecma from France. See National Research Council, *High-Stakes Aviation: U.S.-Japan Technology Linkages in Transport Aircraft* (Washington, D.C.: National Academy Press, 1994).

[61] A great deal of information on IMS is available on-line at the IMS World Wide Web site (http://www.ims.org).

Box 2-2 Japan's International Science and Technology Initiatives

Human Frontier Science Program

The Human Frontier Science Program (HFSP) was first proposed by Prime Minister Nakasone at the 1987 G-7 Economic Summit in Venice. Japan would fund the lion's share of a major program of international collaboration in basic life sciences research. There was some suspicion on the part of western scientists and governments that the program was aimed at gaining access to fundamental research outside of Japan. After two years of international discussions, the program was launched at a smaller scale than originally envisioned.

HFSP funds international collaboration in research on brain functions and molecular level approaches to basic biological functions. The program emphasizes support for intercontinental collaboration, interdisciplinary projects, and younger researchers. The main mechanisms of support are grants, fellowships, and workshops.[1] The program's budget is about $46 million per year, with Japan providing about 80 percent. The United States contributes $4 million through the National Science Foundation and the National Institutes of Health. Canada, several European countries, and the European Union also contribute. The program is managed by a secretariat located in Strasbourg, France, and the proposals are internationally peer reviewed.

One early success for the program was an effort by 16 teams to turn hospital magnetic resonance imaging into a research tool.[2] Over the years of its existence, the program has gained a great deal of favorable recognition from scientists, including a glowing endorsement from an international review panel in 1996.

Despite this widely recognized scientific success, future prospects for the HFSP are uncertain. Japan has been aiming to shift the program toward more balanced funding. In 1992, the participating countries agreed to move toward a target of 50 percent funding from Japan and 50 percent from other partners, but not much progress has been made. Japan is becoming more vocal in prodding the other members to contribute more, particularly the United States, whose researchers receive much more from HFSP than what the U.S. government contributes.[3] A tight science funding environment in most member countries is seen to be the major barrier.

Intelligent Manufacturing Systems

The Intelligent Manufacturing Systems program (IMS) was unveiled by Japan's Ministry of International Trade and Industry (MITI) in the autumn of 1989 as a 10-year, $1 billion international research program to systematize knowledge about manufacturing, standardize future technical approaches, and promote international cooperation.[4] MITI established the IMS Promotion Center as a coordinating body for Japanese members and approached a number of U.S. private sector institutions to enlist participaton. The Society of Manufacturing Engineers was designated as U.S. secretariat, and several U.S.-based companies and universities expressed interest in participating.

The size of the program, the relevance of the announced themes to large future markets, and the aggressive launch of the program featuring direct approaches by MITI to U.S. organizations raised concern among U.S. and European government officials. Advanced manufacturing had been designated as one of the potential technical focus areas under the U.S.-Japan Science and Technology Agreement only a year before. In the spring of 1990, the U.S. government invoked the agreement to call for a moratorium on IMS activities, and designated the Department of

Commerce (DOC) as the lead agency to work with the U.S. private sector, MITI, and other foreign governments to decide how to proceed.

The next steps proceeded along two tracks. At the international level, representatives from Japan, the United States, Australia, Canada, the European Union, and the European Free Trade Area met several times during 1990 and 1991. An International Steering Committee (ISC), International Technical Committee, and International Intellectual Property Rights Committee were formed, and guidelines for a two-year feasibility study were finalized in late 1991.[5]

In the United States, a series of symposia and meetings with interested government, industry, and university representatives was organized by DOC to develop a U.S. response. An Ad Hoc Industry Group made up of about a dozen U.S. companies was formed to refine industry views. Later in the process, a Coalition for Intelligent Manufacturing Systems was formed. These U.S. discussions provided feedback and ideas for the ongoing international negotiations.

A two-year feasibility study was launched in 1992, to test both the feasibility of meaningful international collaboration on advanced manufacturing research as well as the feasibility of international management of the formation of consortia. In January 1993 five test cases and one study project were endorsed by the ISC. Although collaboration involved some difficulties, such as asymmetries in availability of funding for participants from different countries, and the costs involved with international travel, in early 1994 the ISC recommended that a full-scale IMS be launched.[6] The program would run for ten years, with a review after seven years.

As of May 1997, 10 IMS projects were operating, including four from the initial feasibility study. Sixteen additional projects were in various stages of formation.[7] Despite the delays and misunderstandings that were encountered, the task force sees IMS as a positive example of how a decentralized system such as the United States can formulate a coherent national approach to international science and technology cooperation through public-private consultation.

Real World Computing Program

The Real World Computing Program (RWC), was launched by Japan in 1992 as a 10-year, $500 million effort to develop theory and related applications associated with "flexible information processing."[8] RWC's major research areas are theoretical foundations, novel functions, neural systems, massively parallel systems, and optical systems.

Research is managed by MITI's Electrotechnical Laboratory and the Real World Computing Partnership (RWCP), a consortium of 16 Japanese companies and four foreign research institutions. Part of the research is contracted to public research institutions. RWCP has set up the Tsukuba Research Center as a central lab for coordinating and integrating the distributed work. Intellectual property rights are jointly owned by the Japanese government and RWCP. Updated information about RWC and research results is available on the RWCP home page.[9] RWC plans to hold large international meetings every two or three years.

The United States and Japan collaborate in one aspect of the RWC, known as the Joint Optoelectronics Program (JOP). JOP is a jointly run broker service that links designers of advanced systems for computing requiring optoelectronic devices and modules with suppliers of these components. The Japanese broker is the Optoelectronics Industry and Technology Development Organization. The U.S. broker team consists of the Optoelectronics Industry Development Association, the Microelectronics and Computer Technology Corporation, and the MOSIS service of the Information Sciences Institute of the University of Southern California.[10]

The JOP is currently operating on a trial basis until 1998. As of May 1997, 12 transactions had been completed or were in process.

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[1]Human Frontier Science Program, *HFSP Activities*, March 1997.

[2]Nigel Williams, "Funding Inequality Threatens Novel Bioscience Program," *Science*, December 13, 1996.

[3]Ibid.

[4]George R. Heaton, Jr., *International R&D Cooperation: Lessons from the Intelligent Manufacturing Systems Proposal, Manufacturing Forum Discussion Paper No. 2* (Washington, D.C.: National Academy Press, 1991).

[5]U.S. Department of Commerce, *IMS: Final Report of the International Steering Committee* (Washington, D.C.: U.S. Government Printing Office, 1994).

[6]Ibid.

[7]See the IMS home page on the World Wide Web, at <http://www.ims.org>, for updated information.

[8]See David J. Kahaner, ONR Asia, "Draft of R&D master plan for Real World Computing Program," January 1992, and "Real World Computing, Symposium and Projects," June 1994. At different stages of development, the project has been known formally or informally as the New Information Processing Technology Development Program, the Sixth Generation Computer Program, and Four Dimensional Computing. The last is the English translation of the official Japanese name.

[9]See RWCP home page on the World Wide Web at <http://www.rwcp.or.jp>.

[10]See Joint Optoelectronics Project home page on the World Wide Web at <http://www.OIDA.org/JOP>.

modules was launched in 1994 under a U.S.-Japan agreement, while the bulk of the Real World Computing program is being conducted as a Japanese national project, with informal small-scale foreign participation. The Micromachine and Atomic Manipulation consortia have been organized as national projects, and each has several foreign participants with critical expertise.

No new MITI proposals for large international R&D programs have emerged in the past several years as Japan's approaches toward international science and technology cooperation have shifted. In recent years MITI has launched smaller-scale international technology initiatives in Asia, such as a center to demonstrate environmental technologies in China, and has proposed collaborative R&D projects under the Asia Pacific Economic Cooperation forum.[62]

At the same time, Japanese companies also undertook their own extensive efforts to tap foreign technological capabilities during the 1980s and 1990s, including overseas R&D facilities, collaborative R&D with foreign universities, particularly U.S. ones, and acquisition of foreign high-technology start-ups. These linkages also raised concerns in the United States. Although the number of new investments and programs has fallen in the past few years, anecdotal evidence indicates that at least some Japanese companies are continuing their focus on international collaboration in fundamental science and engineering research related to their core businesses.[63]

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[62] For a summary of Japanese government efforts in this area, see National Science Foundation Tokyo Office, "Japan's Technical Cooperation with Asian Countries," Report Memorandum #96-17, July 1996.

[63] There are no comprehensive reliable data on foreign corporate funding of U.S. university research. A 1993 report by the Office of Technology Assessment contains a conservative estimate that Japanese companies fund perhaps $50 million of U.S. university research per year, representing about two-thirds of all foreign corporate funding and less than 5 percent of the total industry support. See U.S. Congress, Office of Technology Assessment, *Multinationals and the National Interest: Playing by Different Rules* (Washington, D.C.: U.S. Government Printing Office, 1993), pp. 108-109. Although Japanese companies are gradually expanding research ties with Japanese universities as well, foreign institutions often are more capable and flexible. See "Universities and Companies Learn Benefits of Teamwork" in *Science*, op. cit., pp. 1174-1175. There are also indications that Japanese companies are stepping up efforts to establish

The results or long-term impacts of these efforts by Japanese companies are still difficult to assess. Investments in foreign high-technology start-ups or universities involve higher technological and business risks than traditional patterns of arms-length licensing of proven technologies. Still, there have been significant changes in how Japanese companies approach international collaboration. The best examples perhaps come from the semiconductor industry, where many observers in Japan and the United States believe that U.S.-Japan corporate alliances have become more reciprocal and balanced in recent years, particularly in terms of expanding opportunities for market participation, and in some cases more symmetrical in terms of technology flows. For example, the foreign share of the Japanese semiconductor market rose from 8 percent in 1986 to over 30 percent in 1996.[64] Another factor that has had an influence across a number of high technology industries is change in intellectual property rules, particularly in the United States.[65]

New Challenges

In recent years, Japanese companies in several industries have been challenged by resurgent U.S. companies and companies based in Asia. Despite industry and government initiatives designed to improve Japan's capability to independently generate fundamental innovations and effectively access foreign innovation, results have been slow to appear. Recent Japanese success stories—LCD displays and video games are perhaps the best examples—have been built on traditional patterns of technology importation and modification for novel applications. Although Japan faces challenges, the institutions and capabilities underlying Japanese innovation possess deep strengths, which the task force believes will reassert themselves in perhaps unexpected ways.[66] One critical question is how the accelerating movement of manufacturing activities offshore by Japanese companies will affect their long-term technological capabilities and competitiveness.[67] Also, the Science and Technology Basic Law and Basic Plan are evidence of renewed efforts to build a stronger basic research base and to reduce dependence on U.S. fundamental research. The long-term impact of these measures will ultimately depend on the

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R&D facilities overseas, after a lull of several years. See "Kenkyu kyoten, kaigai ni" (Establishing research facilities abroad), *Nihon Keizai Shimbun,* June 1, 1995, p. 1.

[64] There is considerable disagreement over the role that the U.S.-Japan Semiconductor Trade Agreement played in this shift. The agreement was signed in 1986 and renewed in 1991. In 1996, the agreement was replaced with an industry-to-industry agreement and a joint government announcement. For positive analyses of the agreement's role, see Laura D'Andrea Tyson, *Who's Bashing Whom? Trade Conflict in High-Technology Industries* (Washington, D.C.: Institute for International Economics, 1992) and The American Chamber of Commerce in Japan, *Making Trade Talks Work: Lessons from Recent History* (Tokyo: ACCJ, 1997). For analysis that argues that the agreement had a marginal or negative impact, see Bryan Johnson, "Let the U.S.-Japan Semiconductor Agreement Expire," Heritage Foundation, May 1996.

[65] The basic differences between U.S. and Japanese intellectual property protection regimes and enforcement are fairly well known. It remains relatively more difficult for inventors to protect intellectual property in Japan than in the United States. Still, strengthening of U.S. intellectual property protection over the past 15 years, combined with the ability to exclude imports that infringe on U.S. patents, has given U.S. innovators greater leverage in dealing with Japanese companies than was the case in the past. See National Research Council, *Corporate Approaches to Protecting Intellectual Property* (Washington, D.C.: National Academy Press, 1994).

[66] Chapter 5 contains review and analysis of these strengths on a sectoral level.

[67] Eileen M. Doherty, ed., *Japanese Investment in Asia: International Production Strategies in a Rapidly Changing World* (Berkeley, Calif.: The Asia Foundation and Berkeley Roundtable on the International Economy, 1995).

capacity of Japanese government, industry, and universities to change their habits, relationships, and technical culture.

3
Science, Technology, and Innovation in the United States

SUMMARY POINTS

• *The United States gained world leadership in a number of the technologies and industries of the "second industrial revolution"—electrical machinery, automobiles, and steel—through the development of large-scale mass production techniques. World War II spurred several changes in U.S. innovation whose impacts are felt even now: a large federal role in supporting R&D, a focus on defense needs, and the critical role of small entrepreneurial firms in commercializing new technologies.*

• *Beginning in the 1960s, a number of U.S. industries have been severely challenged in international competition. Over the past decade or so U.S. industry has made great progress in adapting to flexible production systems and linking technology development more effectively to products and markets. However, long-term barriers to sustained growth and productivity gains remain, such as the uneven quality of K-12 education and a low savings rate. The United States remains very strong in innovation, particularly in information technologies and related fields, as well as biotechnology and other newer technologies. With the end of the Cold War and the new challenges of international competition, the role of the federal government in innovation has been hotly debated.*

DEVELOPMENTS PRIOR TO WORLD WAR II

Like Japan, many of the key features of technological innovation in the United States are long standing. For example, the inflow of technologies from abroad played a major role in U.S. industrial development, particularly in the late nineteenth century. In contrast to Japan, however, where arms-length licensing and joint ventures have been the preferred mechanisms, technology has often flowed to the United States in the form of immigrant scientific and engineering talent and through foreign investment. During America's early industrialization, immigrant engineer-entrepreneurs played a significant role in technology and enterprise development.[1] Another consistent feature is the role of military needs in pushing innovation. Although the United States has maintained a relatively small military establishment for much of its history, military science and technology often had a major influence on civilian innovation even prior to World War II, including the development of milling machines and the principles of mass production and interchangeable parts at government arsenals in the mid-nineteenth century.[2]

[1] John H. Dunning, *Multinational Enterprises and the Global Economy* (Wokingham, England: Addison-Wesley, 1993).

[2] Harvey Brooks, "National Science Policy and Technological Innovation," in Ralph Landau and Nathan Rosenberg, eds., *The Positive Sum Strategy: Harnessing Technology for Economic Growth* (Washington, D.C.: National Academy Press, 1986), p. 121.

The half century between the end of the Civil War and the outbreak of World War I was marked by rapid industrialization and economic growth. A number of factors underlying U.S. innovation and growth were similar to those later enjoyed by Japan during the half century following World War II. A favorable U.S. security environment allowed relatively low defense spending. High trade barriers encouraged the growth of domestic manufacturing industries and the inflow of foreign technologies. Just as Japan's access to an integrating global economy in recent decades allowed scale-intensive manufacturing to prosper, rapid population growth and the development of transportation infrastructure gave late nineteenth century America the largest common market in the world. This context favored low-cost, high-volume manufacturers of standardized goods, and U.S. companies responded by developing production systems characterized by capital intensity and specialization in order to minimize costs over long production runs.[3] The challenge of managing a heterogeneous work force was met by dividing operations into narrow, relatively unskilled tasks. U.S. manufacturing was characterized by larger, more efficient mass production operations than those of other countries. By 1913, U.S. productivity and per capita income exceeded those of Great Britain.[4]

Innovation during this period did not rely on indigenous scientific research.[5] The U.S. government generally did not see support for science as a legitimate public function in peacetime until after World War II, but it did support the development of technology and innovation directly and indirectly through policies linked to specific national purposes. Policies that supported the growth of key institutions and infrastructure underlying industrial development—the railroads and land grant colleges, for example—are well known. The late nineteenth and early twentieth centuries also saw the establishment of government agencies to support the development and diffusion of applied technologies, such as the Agricultural Research Service, National Bureau of Standards, U.S. Geological Survey, and the National Advisory Committee for Aeronautics.[6]

As a result of new antitrust laws enacted around the turn of the century, U.S. companies were constrained from utilizing informal price-fixing agreements between firms to control markets. Many turned to horizontal mergers and industrial research and innovation as alternative mechanisms for growth and differentiation.[7] During the first half of the twentieth century, Du Pont, AT&T, General Electric, and other leading companies established research facilities, which expanded from an initial focus on quality control and materials analysis to external technology monitoring and the development of new products and processes.[8] The large corporations that spearheaded the growing utilization of scientists and engineers in corporate research were concentrated in the chemical, petroleum, and electrical machinery sectors. By the end of World War II, the transportation equipment sector also had become a major performer of R&D because of the growth of the automobile and aerospace industries.

During the 1930s, federal expenditures for R&D accounted for less than 20 percent of the total national effort, comparable to the situation in Japan today.[9] Industry accounted for two-thirds. Scientific and engineering research at universities grew considerably in scale and quality during the first half of the century, supported largely by state governments and private

[3] David C. Mowery and Nathan Rosenberg, "The U.S. National Innovation System," in Richard R. Nelson, ed., *National Innovation Systems: A Comparative Analysis* (New York: Oxford University Press, 1993), p. 31.

[4] Ibid.

[5] Ibid.

[6] Brooks, op. cit., p. 119.

[7] Mowery and Rosenberg, op. cit., p. 32.

[8] Ibid.

[9] Ibid, p. 35. The U.S. Department of Agriculture was the largest federal R&D spender, accounting for 39 percent of the $74.1 million budget in 1940.

foundations. Because the U.S. university system was decentralized and much of it was state supported, new research and academic programs responsive to the needs of local industries flourished.[10]

THE ENDLESS FRONTIER

World War II and its aftermath brought significant changes in the institutional arrangements underlying U.S. technology development and innovation. The two seminal military R&D efforts of the war—the Manhattan Project and the development of radar—established patterns that continue to exert influence today. The former, which was the largest and most expensive technological enterprise in history, developed the atomic bomb and influenced the structure and management of large postwar government R&D projects in defense, nuclear energy, and space.[11] The Manhattan Project also created a world-class concentration of talent and physical infrastructure in basic and applied engineering in the United States, a capability that evolved into today's system of multi-program national laboratories. The development of radar, in which the Radar Laboratory at the Massachusetts Institute of Technology played the key coordinating role for military users, academic researchers, and industrial manufacturers, demonstrated the potential power of interdisciplinary and cross-sectoral linkages. The success of these and other wartime technological efforts led to growing influence in policymaking by the scientists and engineers in charge of them. It seemed natural to some that a continuing large federal role could have a similar beneficial impact on meeting peacetime needs.[12] The onset of the Cold War ensured support and further development of the research establishment built during the war. The key elements in U.S. science and technology policy since that time have included (1) federal funding for half or more of the national R&D enterprise; (2) federal funding focused primarily on defense and secondarily on other agency missions such as space and public health, as well as on maintaining a strong base in basic science; and (3) the bulk of federally-funded R&D performed by industry and universities rather than government-operated laboratories.[13]

The large corporations that dominated U.S. industry continued to build on their strong technological foundations following the war. There was a significant long-term expansion in the employment of scientists and engineers by industry, and a number of companies established large central research facilities. During the 1950s and 1960s, many large U.S. companies expanded their horizons to international markets, based on the competitive strength gained in the United States. Emerging U.S.-based multinational corporations did not hesitate to establish production facilities overseas rather than rely on exports when this appeared to make sense in light of economic conditions, such as the strength of the U.S. dollar.

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[10] A good example is the growth of a specialized chemical engineering discipline in the United States. See Ralph Landau and Nathan Rosenberg, "Successful Commercialization in the Chemical Process Industries," in Nathan Rosenberg, Ralph Landau, and David C. Mowery, eds., *Technology and the Wealth of Nations* (Stanford, Calif.: Stanford University Press, 1992), pp. 81-82.

[11] Robert Teitelman, *Profits of Science: The American Marriage of Business and Technology* (New York: BasicBooks, 1994), pp. 22-32.

[12] Vannevar Bush, et al., *Science the Endless Frontier: A Report to the President on a Program for Postwar Scientific Research*, July 1945.

[13] For example, the Federal government funded about 64 percent of total U.S. R&D in 1960, and about 57 percent in 1970. The Federal share dropped below half in 1978, but held between 45 and 50 percent until 1989. By 1995, the Federal share had fallen to about 35 percent. See National Science Board, *Science & Engineering Indicators-1996* (Washington, D.C.: U.S. Government Printing Office, 1996).

Since the 1950s, smaller entrepreneurial firms have played a critical role in developing and commercializing new technologies in the United States, an innovation pattern that is somewhat unique in the world. This trend was directly and indirectly supported by the changing federal role in U.S. innovation. For the first several postwar decades, the impact was greatest on the emerging semiconductor and computer industries. Increased support for basic research at universities meant that many innovations were pioneered in academia, providing opportunities for researchers to start companies in order to commercialize these new technologies. The willingness of the U.S. military to incorporate the products of small inexperienced firms allowed start-ups to grow quickly by focusing their early marketing efforts on this single critical customer. Fundamental technologies developed in larger firms were often made available to newcomers at reasonable terms as a result of U.S. government antitrust policies. As time passed and a number of small companies achieved success, new financial institutions were established to provide patient risk capital to fund start-ups. This complex of entrepreneurial technical talent and a supportive market and financial environment led to the growth of high-technology manufacturing regions, the most significant appearing in Northern California (Silicon Valley) and Massachusetts (Route 128). A similar complex of technical entrepreneurs and institutions for capital formation has more recently supported the development of commercial biotechnology and software. The passage of the Bayh-Dole Act in 1980, which allowed universities to own the results of government-sponsored research, provided further impetus.[14]

Military R&D and procurement have had a pronounced impact on postwar innovation in the United States. In some cases this influence has been felt through direct military to commercial spinoffs. A classic example is the jet engine, which was developed in Europe but was more quickly and effectively applied by U.S. companies in both military and commercial aircraft, allowing the United States to establish a leading position in this industry. Military funding supported many of the key innovations in microelectronics and computers, but the product demand from weapons systems probably constituted a larger contribution to the development of these industries than direct R&D support.[15]

THE COMPETITIVENESS CRISIS AND RESPONSES

During the 1960s and 1970s, many U.S. manufacturing companies and industries began to lose competitiveness in international and domestic markets. In the case of steel, automobiles, and consumer electronics, this loss of competitiveness constitutes the flip side of the Japanese gains made during this period, as described above. In automobiles, for example, U.S. companies did not experience serious foreign competition in the U.S. market for many years, and emphasis on more profitable larger cars left a window of opportunity that the Japanese were able to exploit in the 1970s when gasoline shortages led to a surge in demand for smaller vehicles. Once the fundamental barriers to entry were breached, the flexible production strengths and resulting

[14] Although there is some disagreement over the contribution of Bayh-Dole, the task force believes that the favorable case is quite strong, particularly in biotechnology. Since its passage in 1980, university patenting has risen dramatically, as has overall industrial support for university research. Surveys of university administrators and industry have confirmed the value of the legislation in providing a general framework for expanded utilization of the results of federally funded R&D. See Wendy H. Schacht, *The Bayh-Dole Act: Patent Policy and the Commercialization of Technology,* Congressional Research Service, 1994.

[15] John A. Alic, Lewis M. Branscomb, Harvey Brooks, Ashton B. Carter, and Gerald L. Epstein, *Beyond Spinoff: Military and Commercial Technologies in a Changing World* (Boston, Mass.: Harvard Business School Press, 1992), pp. 257-260.

higher-quality vehicles produced by Japanese firms allowed them to rapidly increase market share.[16] In consumer electronics, Japanese productivity and cost advantages led to incremental market share gains and declining profitability for U.S. competitors. U.S. companies gradually ceded control over manufacturing and almost all of the large U.S. consumer electronics companies have now exited the business. The low value of the yen through much of this period helped Japanese companies establish their initial footholds in the U.S. market.

The industries in which the United States has experienced the greatest competitiveness problems have tended to be the ones in which the Japanese advantages of flexible production—including continuous improvement in manufacturing processes and close interactions between manufacturers and suppliers in product development and production—could be put to work for maximum impact.[17] In the chemical and pharmaceutical industries, where competitiveness is more tightly linked to the generation of product innovations through R&D, U.S. companies have done better in responding to international competition, which has mainly come from Europe rather than Japan. Nevertheless, increasing competition, increased capital costs and an unfavorable macroeconomic environment probably combined to lower the returns to R&D investments, leading to slower growth in U.S. industrial R&D spending during the 1970s.[18]

During the 1980s, as U.S. competitiveness problems mounted, U.S. industry and government developed a number of responses. Limited trade protection encouraged investment by foreign manufacturers and spurred business alliances between U.S. and overseas companies.[19] Over time U.S. manufacturers appear to have made substantial progress in modifying and adapting aspects of flexible production, particularly in the automobile industry. Following Japanese challenges in the semiconductor and computer industries and resulting concerns about the U.S. position in high technology, U.S. government and industry have taken a number of initiatives to better link R&D efforts with market needs. In addition to broad initiatives, such as the establishment of engineering research centers by the National Science Foundation and legislation to facilitate and promote commercial application of technologies developed in universities and national laboratories, several programs were aimed specifically at the then-beleaguered semiconductor industry. These included the Semiconductor Research Corporation, a partnership between industry and universities in research and education, and the SEMATECH government-industry collaborative R&D partnership consortium. Some advocated an even more active role for the federal government in civilian technology development.[20] In the 1990s, new programs to support commercially relevant technologies such as the Advanced Technology Program and the Partnership for a New Generation of Vehicles (PNGV) have expanded rapidly, but intense debate continues over the appropriate federal role in commercial technologies.

Significant changes are occurring along other dimensions of federal involvement in the U.S. R&D enterprise. Among the traditional public missions, the overall share held by defense has declined in recent years, while spending on life sciences research aimed at advances in public health has grown rapidly. Intramural and extramural research programs of the National Institutes

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[16] See Dertouzos, et al., op. cit., pp. 171-187.

[17] In a number of industries Japanese government-industry approaches to technology acquisition and improvement (see Chapter 2) have also played a role.

[18] Mowery and Rosenberg, op. cit., p. 50.

[19] One example is the voluntary export restraints (VER) on Japanese auto exports to the United States. There is wide agreement these restraints led to billions of dollars of transfers from U.S. consumers to auto producers, most of which went to Japanese producers. There is also wide agreement that the VER hastened Japanese auto industry investment in the United States. C. Fred Bergsten and Marcus Noland, *Reconcilable Differences? United States-Japan Economic Conflict* (Washington, D.C.: Institute for International Economics, 1993), pp. 106-107.

[20] National Academy of Sciences, National Academy of Engineering, and Institute of Medicine, *The Government Role in Civilian Technology: Building a New Alliance* (Washington, D.C.: National Academy Press, 1992).

of Health play an important role in sustaining the research base utilized by U.S. pharmaceutical companies. The role of defense R&D and procurement in facilitating the emergence and growth of new commercial technologies has also declined over time, leading some to call for a greater reliance on commercial technologies by the Department of Defense.[21] Cancellation of the Superconducting Supercollider and problems experienced in the development of the space station imply that the future is uncertain for large federal science and technology programs in the mold of the Manhattan Project and the Apollo Program. The future role of the large, multi-program national laboratories also has been increasingly scrutinized and debated.[22]

Rapid change continues in U.S. industry as well. In addition to efforts on the part of U.S. companies to adapt and utilize a flexible production paradigm, many large U.S. companies have restructured their R&D organizations to improve efficiency and responsiveness to market needs and have sought to utilize linkages with suppliers, customers, and universities to spread the costs and risks of technology development.[23] Passage of the National Cooperative Research Act in 1984 and its expansion in 1993 to include production joint ventures have created a more favorable environment for intercompany R&D and production linkages; initiatives such as PNGV could not have been launched under previous policies.[24] Strengthened protection and enforcement of intellectual property rights in the United States appear to be allowing savvy U.S. companies to achieve greater returns on their technology investments.[25]

Perhaps the most promising trends for U.S. industry are occurring in relation to the development and utilization of information technologies. Continuing leadership in this area appears to bode well for increased U.S. competitiveness in new information-related industries and productivity gains in manufacturing and service sectors throughout the economy. Computers and related equipment now account for a substantial portion of U.S. capital equipment expenditures. Another related trend whose implications have not yet been thoroughly examined is the rapid change in the composition of U.S. industrial R&D spending over the past decade, with R&D performance by nonmanufacturing companies growing rapidly. Much of this investment has been focused on information technologies.

An additional factor in the performance of the U.S. economy that merits discussion is capital formation and allocation. In the 1980s, high savings rates among Japanese citizens and long time horizons for Japanese corporate investment appeared to give the Japanese economy a major boost relative to the United States. Certainly, the low savings rate continues to be a long-term problem for the U.S. economy.[26] On the other hand, the open, competitive U.S. market also forces

[21] National Economic Council, National Security Council, Office of Science and Technology Policy, *Second to None: Preserving America's Military Advantage Through Dual-Use Technology* (Washington, D.C.: U.S. Government Printing Office, February 1995).

[22] Task Force on Alternative Futures for the Department of Energy National Laboratories, *Alternative Futures for the Department of Energy National Laboratories* (Washington, D.C.: U.S. Government Printing Office, 1995).

[23] National Research Council, *Corporate Innovation in the United States and Japan: Report of the U.S.-Japan Joint Task Force* (Washington, D.C.: National Academy Press, forthcoming).

[24] Some experts caution that antitrust enforcement has recently become more strict. See Deborah Wince-Smith, "Incentives for Investment in Innovation: The Strategic Role for Government" in *Global Innovation/National Competitiveness* (Washington, D.C.: Center for Strategic and International Studies, 1996).

[25] National Research Council, *Corporate Approaches to Protecting Intellectual Property: Implications for U.S.-Japan High-Technology Competition* (Washington, D.C.: National Academy Press, 1994).

[26] These issues are covered in Competitiveness Policy Council, Capital Allocation Subcouncil, *Lifting All Boats: Increasing the Payoff from Private Sector Investment in the U.S. Economy* (Washington, D.C.: Competitiveness Policy Council, 1995).

businesses to use capital efficiently. In recent years, the U.S. economy has reaped benefits from this efficiency.[27]

Although recent trends in innovation and competitiveness have been favorable for U.S. companies in a number of industries, there is no guarantee that they will continue or that Japanese and other foreign companies will not be able to adapt U.S. innovations more quickly and effectively. Despite progress by some U.S. companies in meeting the demands of global competition, other important aspects of the manufacturing environment, such as inadequate capital formation caused by low savings rates and stagnant growth in real incomes, remain and are likely to persist. The future federal role in science and technology is still subject to intense debate, particularly federal support for applied research and appropriate modes of government-industry partnerships in areas of research that are applied and close to commercialization. What is clear from this examination of overall U.S. and Japanese innovation policies and paradigms is that considerable differences in orientations and capabilities between the two systems remain, despite some measure of evolution and adaptation in each country.

[27] World Trade Organization, "Open Markets-Domestic and Worldwide-Remain the Key to U.S. Economic Growth," October 1996.

4
Statistical and Policy Context for U.S.-Japan Science and Technology Relations

SUMMARY POINTS

• *Japan and the United States are the world's two leading techno-industrial nations. On several important measures of science and technology inputs, such as nondefense research and development spending and full-time researchers, Japan leads the world on a per capita basis. Japan is also planning significant increases in public support for science and technology at the same time that U.S. government R&D spending is likely to remain flat or decrease.*

• *Japan's performance on measures of science and technology outputs also is impressive. The United States still leads the world in the production of scientific and technical literature, and recent U.S. assessments of international capability in critical technologies show the United States ahead or at parity in all areas. However, Japan's contribution to the world's scientific literature is rising steadily, Japanese inventors account for about one-fourth of U.S. patents granted annually, and Japan leads the world in exports of several important high-technology market categories.*

• *Over the past decade the focus on the U.S.-Japan science and technology relationship has grown, and a number of policy changes and new programs have been implemented to develop human resources for cooperating and competing with Japan in science and technology and for facilitating greater U.S. industry access to Japanese scientific and technical information. Although by themselves these efforts will not have a significant short-term impact on U.S. competitiveness or science and technology relationships with Japan, they represent valuable long-term investments in important national human resource and institutional capabilities for maximizing U.S. interests.*

BASIC DATA ON SCIENCE, TECHNOLOGY, AND INNOVATION

By all of the available relevant measures, the United States and Japan are the two leading techno-industrial nations in the world. The tables and figures in this chapter provide an overview of where the two countries stand in terms of human and financial resource inputs to innovation; scientific, technological, and economic outputs; and key aspects of international science, technology, and trade relationships.

Input Measures

Figures 4-1 and 4-2 provide an overall picture of U.S. and Japanese R&D spending in 1993, the most recent year for which comparable data are available, broken down by source of funds (mainly industry and government) and performing sectors (mainly industry, universities, and government). The figures illustrate the relatively larger role of government in funding R&D in

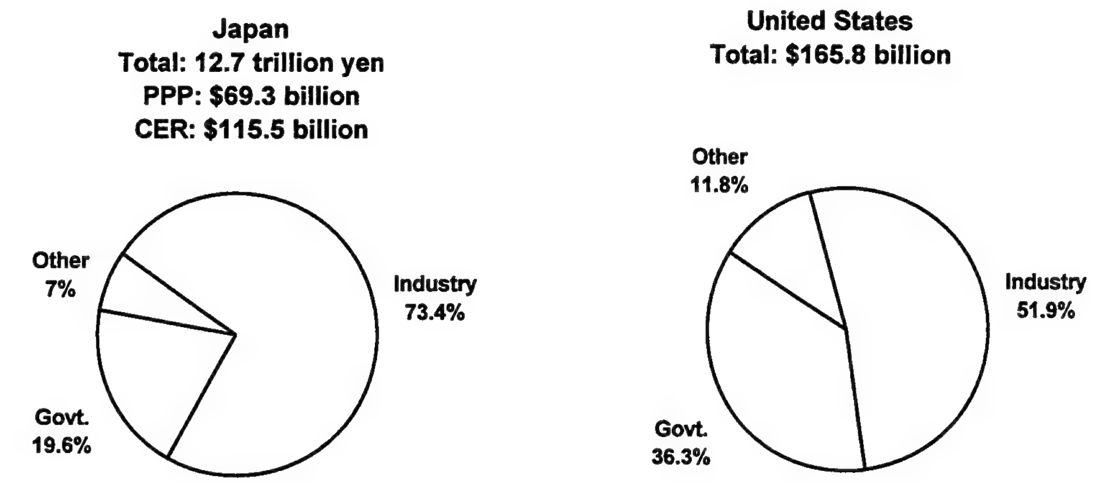

FIGURE 4-1 U.S. and Japanese R&D spending by source of funds, 1993. SOURCE: National Science Board, *Science & Engineering Indicators-1996* (Washington, D.C.: U.S. Government Printing Office, 1996).

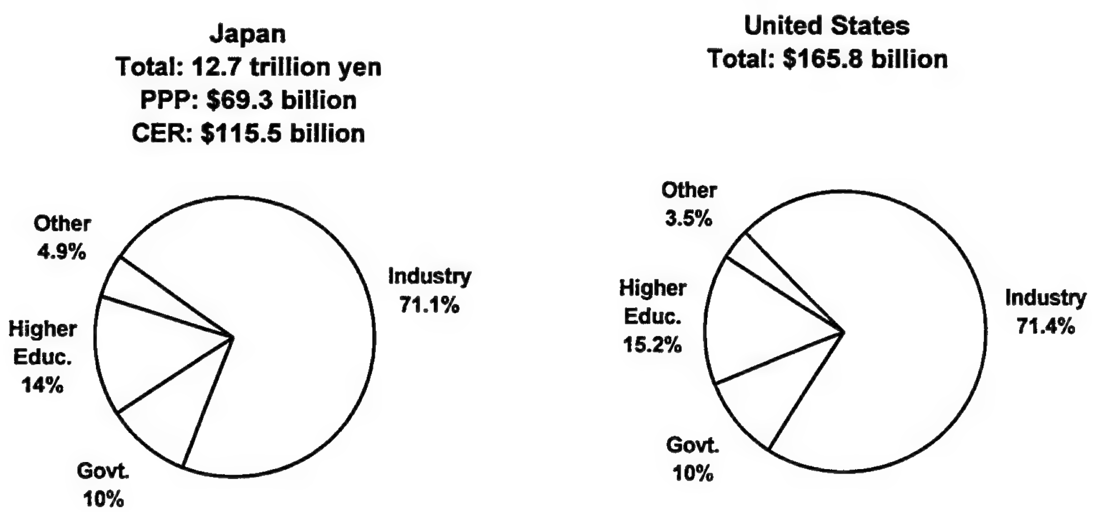

FIGURE 4-2 U.S. and Japanese R&D spending by performing sector, 1993. SOURCE: National Science Board, *Science & Engineering Indicators-1996* (Washington, D.C.: U.S. Government Printing Office, 1996).

the United States. This long standing discrepancy has been narrowing in recent years, mainly because the U.S. government share of overall R&D support has been falling. As Japan follows through on plans to increase government support for R&D in the next few years, it is possible that the two countries will converge toward a 25 to 30 percent level of public support. As for the sectoral breakdown of R&D performance, Figure 4-2 shows that the United States and Japan are quite similar. One caveat that should be mentioned is that many of the activities supported by Japan's general university funds, which are included in the higher-education R&D performance share, would probably not be classified as R&D in the United States. Therefore, the figures may somewhat overstate R&D performed by higher education institutions in Japan.

Another significant difference between the two countries is the emphasis on defense-related R&D in the United States. This is illustrated in Figure 4-3, which shows that Japan is first among leading industrial nations in nondefense R&D expenditures as a share of gross domestic product (GDP).[1] Figure 4-4 shows that Japan leads the world in another important input measure—the number of full-time equivalent R&D scientists and engineers per 10,000 total labor force members.[2]

Figures 4-5 and 4-6 illustrate another important ongoing shift. Figure 4-5 compares Japan's total government science and technology investments for fiscal years 1991-1995 with those of the United States, converted at both purchasing power parity (PPP) and current exchange rates (CER). Figure 4-6 compares prospective government investments over fiscal years 1996-2000. While the Japanese government has stated the goal of spending 17 trillion yen over this period, U.S. government R&D spending is expected to be restrained due to continued efforts to close the federal budget deficit. Assuming that about 6 percent of Japan's total will be defense related, as is true today, Japanese government nondefense science and technology investments over the 1996-2000 period are projected to reach almost 90 percent of the U.S. total at current exchange rates.[3]

Table 4-1 shows industrial R&D performance in the United States and Japan and the breakdown according to industry. The most striking differences in industry composition are the large role of the electrical machinery industry in Japan's industrial R&D and the large percentage of U.S. industrial R&D performed by nonmanufacturing industries. The latter is a relatively recent phenomenon; the nonmanufacturing sector accounted for 4 percent of U.S. industrial R&D in 1982, versus 25 percent in 1992. To some extent, these statistical shifts have resulted from changes in the industrial classification of companies and more thorough surveying of nonmanufacturing companies, so they should be interpreted cautiously. Still, the increased role in U.S. R&D of the packaged software industry (which is classified as nonmanufacturing) and

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[1] In 1994, U.S. and Japanese nondefense R&D expenditures were nearly equal on an absolute basis, $140 billion for the United States and $133 billion for Japan, when measured at current exchange rates. When converted at the purchasing power parity exchange rate, Japan's nondefense R&D spending was $75 billion in 1994. See Organization for Economic Cooperation and Development (OECD), *Main Science and Technology Indicators* (Paris: OECD, 1996).

[2] Aggregate data can mask important differences. Some experts emphasize that the United States has more Ph.D. holders working as researchers in industry than does Japan. Akito Arima, "Strengthening Japan's Science Base: Developments in Education and Research Infrastructure," presentation at the symposium on Science and Science Policy in Japan organized by the Japan Society for the Promotion of Science, March 7, 1997.

[3] A complete review of U.S. and Japanese government R&D funding is outside the scope of this study. There is a significant literature on each country's R&D, much of it cited elsewhere in the report. Those who wish to inquire further might start with National Research Council, *Allocating Federal Funds for Science and Technology* (Washington, D.C.: National Academy Press, 1995), and Science and Technology Agency, ed., *White Paper on Science and Technology 1996: Striving to Become a Front-runner in Research Activity* (Tokyo: Japan Science and Technology Corporation, 1996).

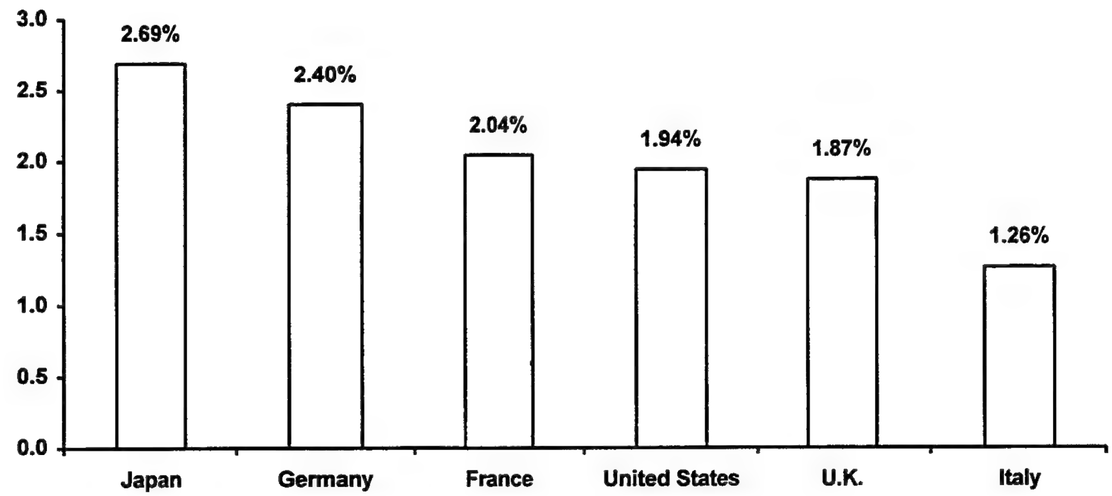


FIGURE 4-3 Nondefense R&D expenditures as a percentage of GDP for most recent year available for each country. NOTE: United States, 1995; Japan, U.K., Italy, and Germany, 1993; France 1992. SOURCE: National Science Board, *Science & Engineering Indicators-1996* (Washington, D.C.: U.S. Government Printing Office, 1996).

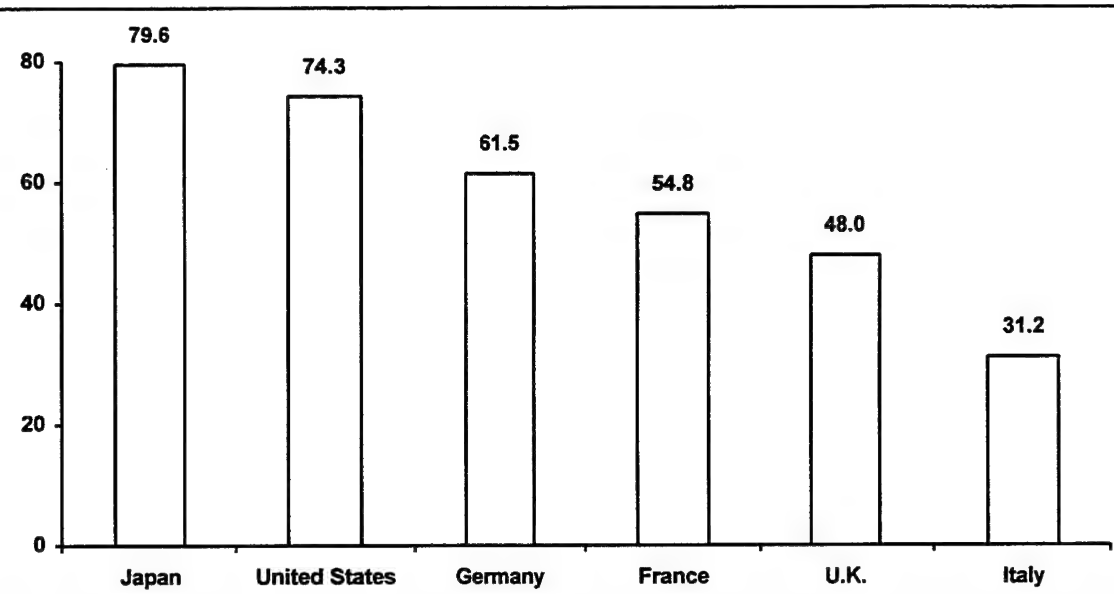


FIGURE 4-4 Number of full-time equivalent R&D scientists and engineers per 10,000 total labor force members, most recent year available for each country. SOURCE: National Science Board, *Science & Engineering Indicators-1996* (Washington, D.C.: U.S. Government Printing Office, 1996).

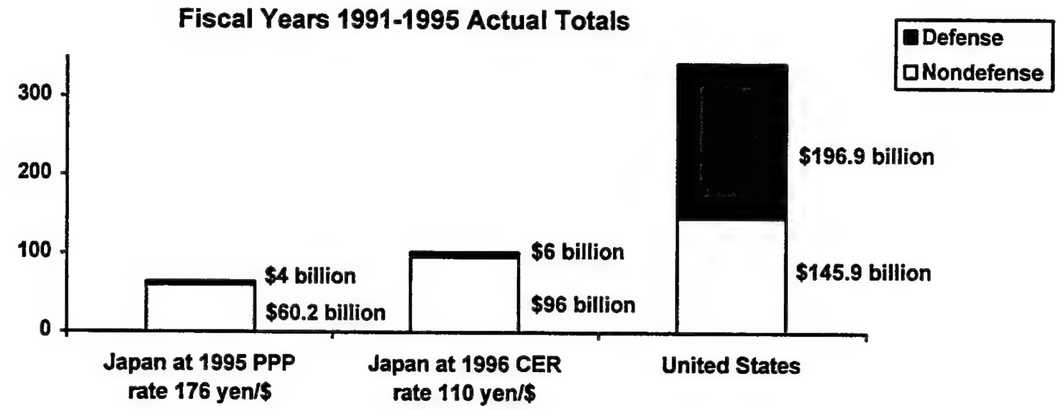


FIGURE 4-5 U.S. and Japanese national government spending on science and technology, actual totals for fiscal years 1991-1995. NOTES: Japan spending in yen: total–11.3 trillion, defense–0.7 trillion, nondefense–10.6 trillion. Figure 4-5 is intended to generally illustrate the magnitude and broad composition of U.S. and Japanese R&D funding, and the exact figures should be taken with some caution. Figures for both countries are in current currency, and do not take into account relative inflation trends. Japanese totals include supplementary budgets. U.S. figures are for budget authority, rather than actual spending. Actual fiscal 1995 spending for the United States was somewhat lower than original budget authority due to two large recision bills during the year. Note that the U.S. total in Figure 4-5 does not include investment in R&D plant, while AAAS projections used in Figure 4-6 do include R&D plant. SOURCES: U.S. Department of Commerce, Office of Technology Policy, *Japanese Government S&T-Related Expenditures*, April 1996, and National Science Board, *Science & Engineering Indicators-1996* (Washington, D.C.: U.S. Government Printing Office, 1996).

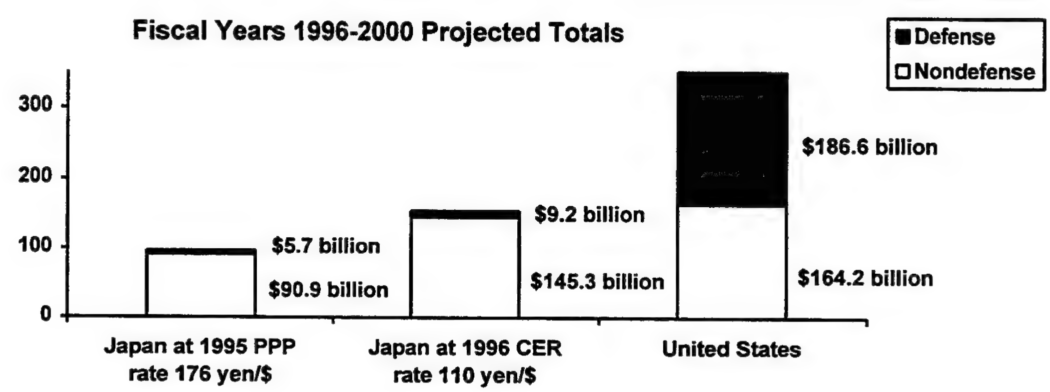


FIGURE 4-6 U.S. and Japanese national government spending on science and technology, projected totals for fiscal years 1996-2000. NOTE: Japanese figures are based on the announced goal of 17 trillion yen and reflect the assumption of defense R&D spending at 6 percent of the total. Figure 4-6 is intended to generally illustrate the magnitude and broad composition of planned U.S. and Japanese government R&D funding, and the exact figures should be taken with some caution. Figures for both countries do not take into account future inflation and exchange rate trends. U.S. figures are for projected budget authority, including R&D plant. Note that the U.S. total in Figure 4-5 does not include investment in R&D plant. SOURCES: American Association for the Advancement of Science and the Japanese science and technology plan.

TABLE 4-1 U.S. and Japanese Industrial R&D Performance, current million dollars

	1982		1987		1992	
United States						
Manufacturing	56,178	(96%)	84,311	(91%)	91,211	(75%)
Chemicals and allied	6,604	(11%)	9,635	(10%)	16,711	(14%)
Machinery	8,078	(14%)	[a]		15,135	(12%)
Electrical equipment	10,923	(19%)	15,848	(17%)	13,546	(11%)
Transportation equipment	[a]		32,246	(35%)	26,484	(22%)
Professional and scientific instruments	3,930	(7%)	5,222	(6%)	9,652	(8%)
Nonmanufacturing	2,472	(4%)	7,844	(9%)	30,103	(25%)
Total	58,650	(100%)	92,155	(100%)	121,314	(100%)
Japan						
Manufacturing	15,082	(93%)	42,077	(94%)	70,639	(94%)
Chemical	2,761	(17%)	7,558	(17%)	12,636	(17%)
Machinery	1,129	(7%)	2,888	(6%)	5,134	(7%)
Electrical machinery	4,724	(29%)	14,921	(33%)	25,358	(34%)
Transportation equipment	2,698	(16%)	6,687	(15%)	11,800	(16%)
Precision machinery	539	(3%)	1,408	(3%)	2,577	(3%)
Nonmanufacturing	1,139	(7%)	2,711	(6%)	4,642	(6%)
Total	16,221	(100%)	44,788	(100%)	75,281	(100%)

[a] Data withheld to avoid disclosing the operations of individual companies.
NOTE: Conversion rates for Japanese figures from International Monetary Fund: 1982, ¥249 per dollar; 1987, ¥145 per dollar; 1992, ¥127 per dollar.
SOURCE: National Science Foundation and Japanese Management and Coordination Agency, Prime Minister's Office.

service industries such as consulting, financial services, and telecommunications services reflects real and important shifts in U.S. innovation.[4]

Output Measures

The measurements given above of inputs to innovation should be interpreted with some caution, since definitions and categories may not be consistent internationally, and it is difficult to measure the quality of certain inputs, even where quantity can be determined. Measuring the outputs of innovation reliably is perhaps even more difficult. Indicators that can serve as proxies

[4] A major question for the future is whether the increased role of the service sector in innovation is a U.S. anomaly or a harbinger of what will occur in Japan and other countries. Countries are moving at various speeds in improving data collection in this area, so international comparisons should be made with caution. See Allison Young, "Measuring R&D in the Services," STI Working Papers, Organization for Economic Cooperation and Development, 1996.

for innovation, such as quantity and quality of scientific and technical literature and patents, productivity growth, market share, and trade performance, may not tell a complete and accurate story. The industry case studies in Chapter 5 are intended to supplement the statistical overview.

Figure 4-7 shows that the United States leads the world in the output of scientific and technical literature by a wide margin, although the U.S. share has been gradually declining since the early 1970s. Japan's share has risen gradually over the years, and stood at 9 percent in 1993, the second-largest single-country share.[5] Table 4-2 gives a breakdown of U.S. patents granted in 1985 and 1995 by residence of the inventor.

Productivity growth is a key element in sustaining a competitive economy that creates high-paying, stable employment over the long term. Figures 4-8 and 4-9 show how the major industrial economies have performed over the past decade in manufacturing and overall

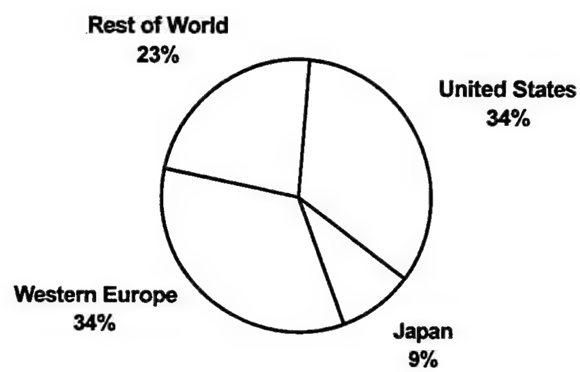


FIGURE 4-7 Country shares of world scientific and technical literature, 1993. SOURCE: National Science Board, *Science & Engineering Indicators-1996* (Washington, D.C.: U.S. Government Printing Office, 1996).

TABLE 4-2 U.S. Patents Granted by Nationality of Inventor

	1985	1995
U.S. residence	55%	57%
Japanese residence	18%	20%
Other	27%	23%
Total patents granted	71,661	113,955

SOURCE: U.S. Patent and Trademark Office.

[5] Contributing to Japan's relative rise over the past decade has been slower growth in output by the United Kingdom and an actual decline in output by the former Soviet Union. See National Science Board, *Science and Engineering Indicators-1996* (Washington, D.C.: U.S. Government Printing Office, 1996), p. 5-31.

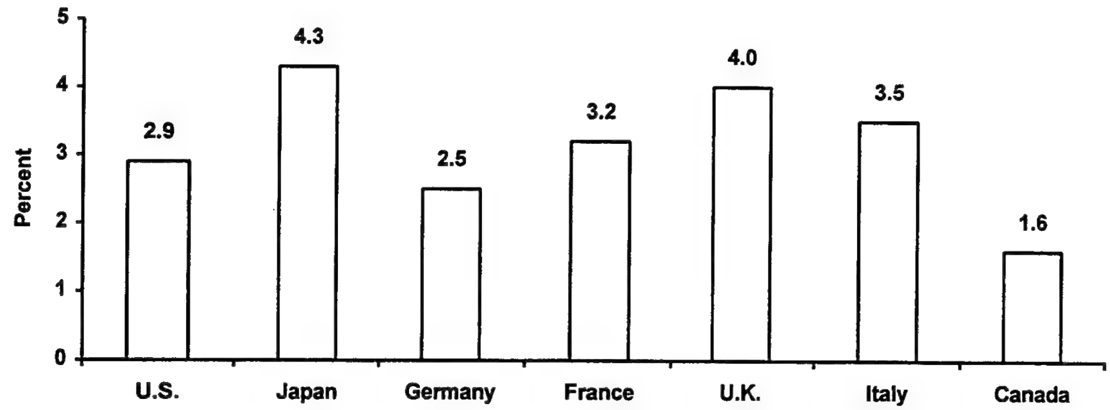


FIGURE 4-8 Compound annual growth in manufacturing productivity, 1985-1995. SOURCE: U.S. Bureau of Labor Statistics, as compiled in *Competitiveness Index 1996: A Ten-Year Strategic Assessment* (Washington, D.C.: Council on Competitiveness, 1996).

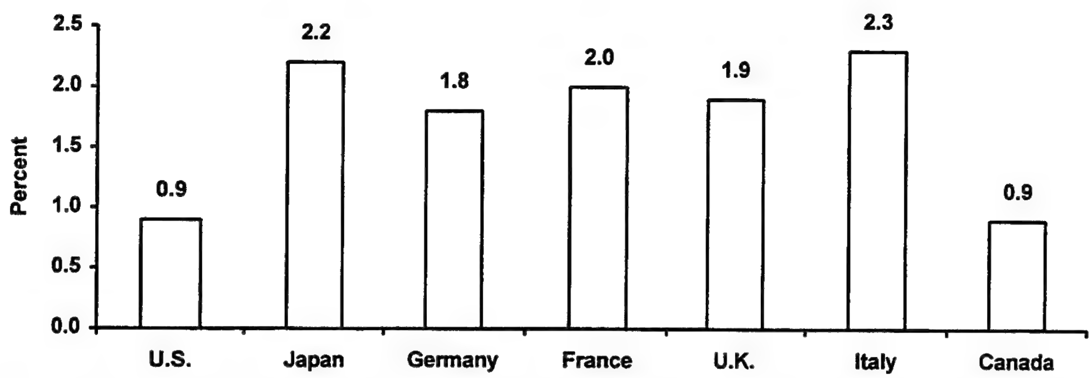


FIGURE 4-9 Compound annual growth in national productivity, 1985-1995. SOURCE: WEFA Group, as compiled in *Competitiveness Index 1996: A Ten-Year Strategic Assessment* (Washington, D.C.: Council on Competitiveness, 1996).

productivity. The U.S. economy has been a mediocre performer compared with Japan along these measures. The poor U.S. showing in overall productivity compared with manufacturing productivity is due to several factors. Productivity growth in the service sector has been slower than in manufacturing, and U.S. savings and investment levels have been lower than those of most other developed economies.[6]

Figure 4-10 shows the relative share of major countries and regions in world GDP in 1988 and 1993. Japan and other nations in Asia have gradually increased their share of world GDP, while the shares of the United States and the European Union (EU) have declined.

[6] In addition, measuring productivity and productivity growth in the service sector is more difficult than in manufacturing, which means that U.S. performance may be understated in the statistics. More sophisticated approaches to measurement are required. See *Competitiveness Index 1996: A Ten-Year Strategic Assessment* (Washington, D.C.: Council on Competitiveness, 1996), p. 31.

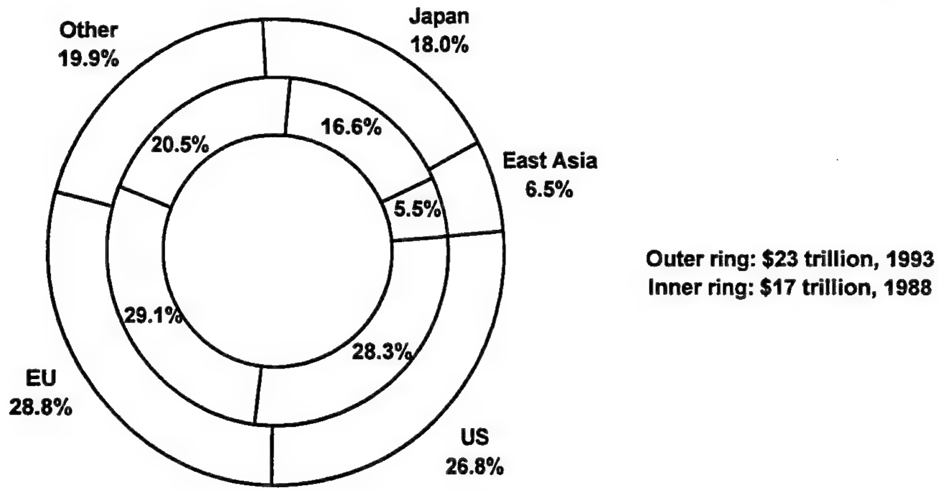


FIGURE 4-10 Percentage of major countries and regions in world GDP. NOTES: Because data for Luxembourg and Taiwan are not available in the *World Development Report*, these are taken from *Main Economic Indicators* and *Key Indicators of Developing Asian and Pacific Countries*. They are added to the World Bank estimates to get the world total. The EU is composed of 15 countries. SOURCES: World Bank, *World Development Report 1995*; Asian Development Bank, *Key Indicators of Developing Asian and Pacific Countries 1995*; Organization for Economic Cooperation and Development, *Main Economic Indicators*.

Figure 4-11 summarizes the results of the U.S. government's periodic assessment of the U.S. technology position compared with Japan and Europe in a range of significant industrial technologies. In contrast with past surveys, the U.S. position is quite strong, with the chart showing no technologies in which the United States is lagging. Figure 4-12 shows the results of a recent Japanese assessment of Japanese industrial R&D capability relative to the United States and Europe. Such assessments represent snapshot judgments by experts in these fields. Although it is possible to make too much of such results, these surveys do support the widely held notion that U.S. industry has improved its performance in innovation and product development across a range of industries in recent years.[7]

Scientific, Technological, and Economic Relationships

An examination of several indicators of U.S. and Japanese scientific, technological, and economic relationships confirms long-standing patterns and reveals several interesting trends. Table 4-3 shows U.S. "arms-length" technology trade, or royalty and licensing payments, between U.S. and nonaffiliated foreign residents. Technology trade with Japan constitutes the bulk of the U.S. surplus in this area. In one sense this can be seen as unfavorable in that far more

[7] This view is supported by Japanese assessments, such as Sangyo Kozo Shingikai Sogo Bukai Sangyo Gijutsu Shoiinkai (Industrial Structure Advisory Committee, Industrial Technology Subcommittee) and Sangyo Gijutsu Shingikai Sogo Bukai Kikaku Iinkai (Industrial Technology Advisory Committee, Planning Subcommittee), *Kagaku Gijutsu Sozo Rikkoku e no Michi o Kirihiraku Shiteki Shisan no Sozo, Katsuyo ni Mukete,* (Clearing a Path Toward a Nation Based on Creative Science and Technology; Toward Creating and Utilizing Intellectual Assets), Executive Summary, June 1995.

US Technology Position Relative to:
Japan ▷ ◁ ○
Europe ▶ ◀ ●
1990–94 Trend
Improved ▷
Declined ◁
Maintained ○

	Lag		Parity	Lead	
	Substantial	Slight		Slight	Substantial
Energy					
Energy efficiency			▶	○	
Storage, conditioning, distribution, and transmission			●	○	
Improved generation			●	○	
Environmental quality					
Monitoring and assessment				◁ ◀	
Pollution control			○ ●		
Remediation and restoration			◀	◁	
Information and communication					
Components			▷	●	
Communications				●	◁
Computing systems				●	◁
Information management					▷
Intelligent complex adaptive systems*			○	◀	
Sensors			▷ ▶		
Software and toolkits				●	▷
Living systems					
Biotechnology				○ ▶	
Medical technologies				▷ ●	
Agriculture and food technologies				◁ ▶	
Human systems				▶	▷
Manufacturing					
Discrete product manufacturing				○ ●	
Continuous materials processing*			○ ●		
Micro/nanofabrication and machining			▷	●	
Materials					
Materials				◁ ●	
Structures				●	◁
Transportation					
Aerodynamics				●	◁
Avionics & controls				◀	◁
Propulsion & power				◁ ●	
Systems integration				●	○
Human interface					▷ ▶

*Based on limited information

FIGURE 4-11 National critical technologies: technology position and 1990-1994 trend. SOURCE: *National Critical Technologies Report* (Washington, D.C.: National Critical Technologies Review Group, 1995), p.vii.

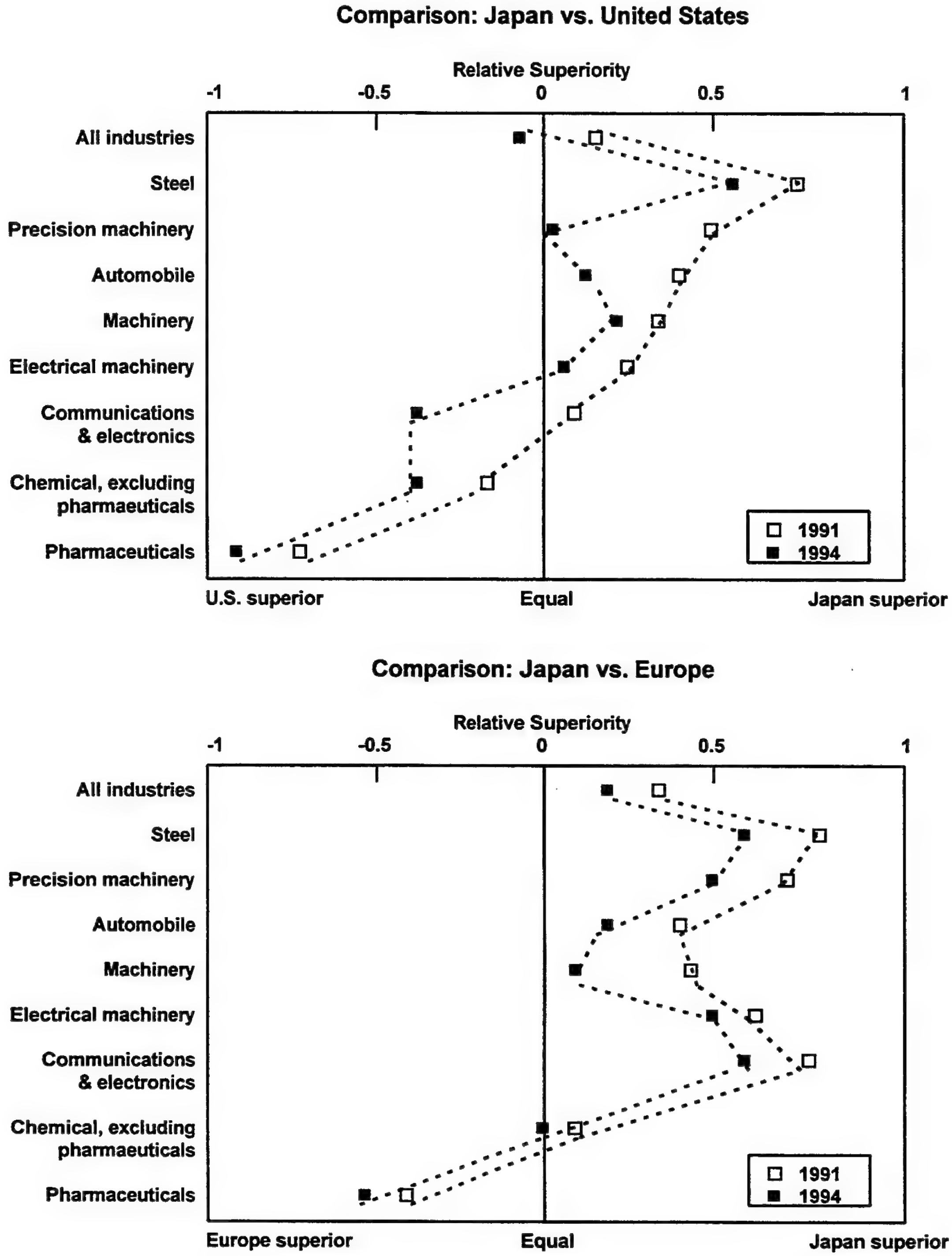


FIGURE 4-12 R&D capability of business enterprises: comparisons between Japan and the United States, and Japan and Europe. NOTE: +1 point was given when a business enterprise assessed Japan to be superior, 0 for equal, and -1 for United States (or Europe) superior, and the sum was divided by the number of business enterprises giving an evaluation to compute the index for evaluating the relative superiority. SOURCE: Japan Science and Technology Agency, *Survey of Private Enterprises' Research and Development*, for FY 1991 and FY 1994.

TABLE 4-3 Receipts and Payments of Royalties and License Fees, 1993—U.S. "Arms-Length" Technology Trade (current million dollars)

	Receipts	Payments	Balance
Europe	615	801	-186
Japan	1,392	194	1,198
Asia, excluding Japan	540	9	531
Rest of the world	208	32	176
Total	2,755	1,036	1,719

NOTE: Receipts and payments of royalties and licensing fees generated from the exchange and use of industrial processes with unaffiliated foreign residents. SOURCE: National Science Board, *Science & Engineering Indicators-1996* (Washington, D.C.: U.S. Government Printing Office, 1996).

U.S. technology still flows to Japan through arms-length transactions than the reverse. On the other hand, the rise in U.S. receipts of licensing fees and royalties certainly reflects the continued strength of the United States in generating innovation, and may also reflect an enhanced ability on the part of U.S. inventors to protect their intellectual property and earn adequate returns on their innovations. Asian countries other than Japan are increasing their licensing and royalty payments to U.S. inventors and may pass Europe in the next few years.

Japan's technology imports and exports for 1994 are given in Table 4-4. These are measured somewhat differently than the U.S. figures and show that Japan has an overall surplus over the rest of the world in technology trade. Asia is the largest purchaser of Japanese technologies, and the United States is the leading source of Japan's technology imports.[8]

Figure 4-13 shows the flow of scientists between Japan and other regions. Japan still sends three to four times as many scientists and engineers abroad than travel to Japan, but the latter number grew rapidly during the first half of the 1990s. The increase in Asian scientists and engineers traveling to Japan is particularly conspicuous. Table 4-5 shows that the United States is also an important destination for Asian scientists and engineers seeking advanced training and research opportunities. Almost 30 percent of U.S. science and engineering doctorates awarded in 1995 went to citizens of Asian countries.[9]

Tables 4-6 and 4-7 cover trade relationships. Table 4-6 shows 1994 U.S. trade in advanced technology products. The United States has an overall surplus, despite a large deficit with Japan and a deficit with Asian countries outside Japan. Asia is the largest regional market for U.S.

[8] Japan has two sets of technology trade statistics. Those presented here are based on an annual survey by the Management and Coordination Agency. The Bank of Japan also compiles statistics on technology trade. The two series cover different sets of companies and are calculated differently. In particular, the level of Japanese technology imports is much higher in the Bank of Japan statistics, which show a large Japanese deficit. The Management and Coordination Agency data are more widely used. Japan's National Institute of Science and Technology Policy (NISTEP) also conducts an annual survey of technologies introduced into Japan. For an overview, see Fujio Niwa, Hiroyuki Tomizawa, Fumito Hirahara, Fumihiko Kakizaki, and Orlando Camargo, *The Japanese Science and Technology Indicator System* (Tokyo: NISTEP, September 1991), pp. 207-214.

[9] As Table 4-5 shows, the number of Japanese citizens receiving science and engineering doctorates in the United States is quite small. Anecdotal information indicates that Japanese companies often send researchers for visits of several months or more to university labs in the United States, but data on these arrangements is difficult to come by.

TABLE 4-4 Japan's Corporate Technology Trade, 1994 (current million dollars)

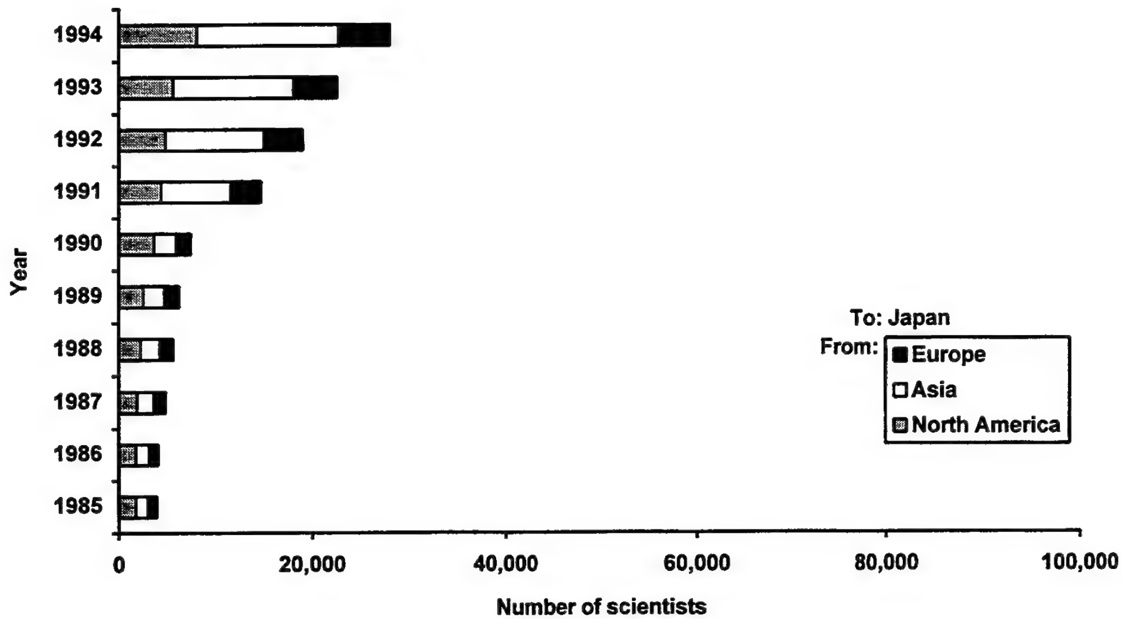
	Exports	Imports	Balance
United States	1,366	2,554	-1,188
Asia	2,122	8	2,114
People's Republic of China	170	1	169
Taiwan	294	1	293
South Korea	521	3	518
Philippines	27		27
Thailand	355		355
Indonesia	149		149
Malaysia	212		212
India	42		42
Europe	794	1,056	-262
Rest of the world	248	16	232
Total	4,530	3,634	896

NOTE: The exchange rate used is 102 yen/dollar—1994 average from International Monetary Fund, International Financial Statistics. SOURCE: Japan Economics Institute, *JEI Report*, September 27, 1996.

TABLE 4-5 Science and Engineering Doctorates Awarded by U.S. Universities, 1995

	Number	% of Total
To U.S. citizens	16,022	60
To non-U.S. citizens	10,493	40
China	2,751	10
Taiwan	1,239	5
India	1,204	5
Korea	1,004	4
Japan	154	0.06
Other Asia	1,308	5
Total Asia	7,660	29
Europe	1,253	5
North America	505	2
Africa	424	2
South America	358	1
Pacific/Australia	203	1
Total	26,515	

SOURCE: National Science Foundation, "Science Resources Division Data Brief," August 19, 1996.



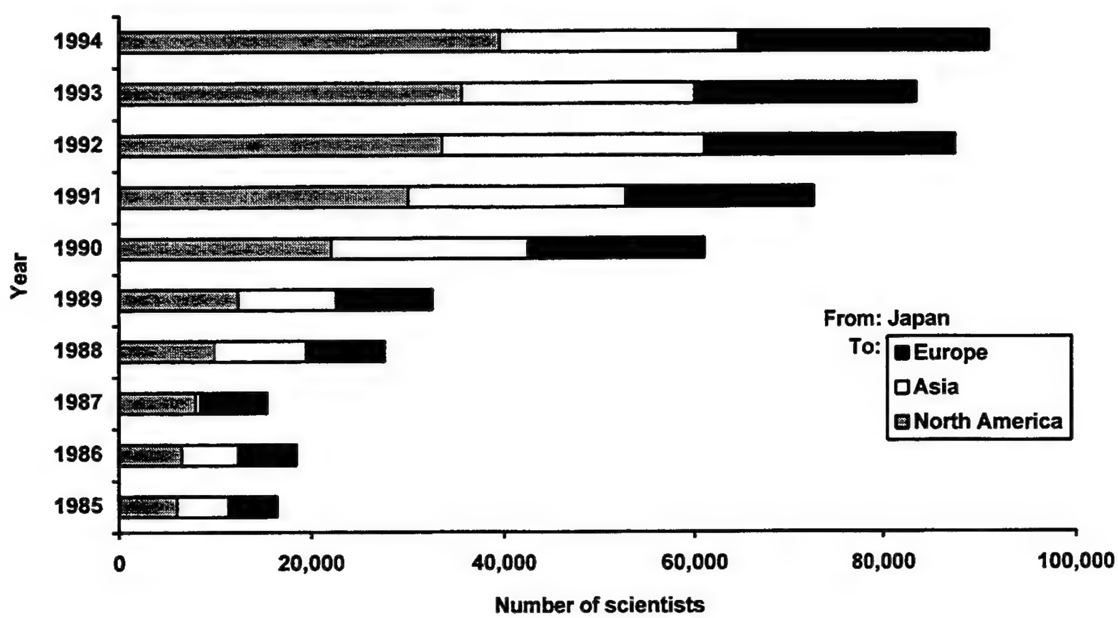


FIGURE 4-13 Flow of scientists to and from Japan. SOURCE: Japan Ministry of Justice as compiled in *Science*, October 4, 1996, vol. 274.

TABLE 4-6 U.S. Trade in Advanced Technology Products, 1994 (current billion dollars)

	Export	Import	Balance
NAFTA partners	19.0	10.9	8.1
Europe four [a]	25.3	14.0	11.3
Japan	14.4	28.7	-14.3
Asia, excluding Japan	30.0	35.2	-5.2
Rest of the world	32.1	9.6	22.5
Total	120.8	98.4	22.4

[a] UK, Germany, France, and Italy.

SOURCE: National Science Board, *Science & Engineering Indicators-1996*, (Washington, D.C.: U.S. Government Printing Office, 1996).

TABLE 4-7 Japan's Trade by Region, 1995 (current billion dollars)

	Imports	% Change from 1994	Exports	% Change from 1994
United States	75.4	20.3	120.9	2.8
EU	48.8	25.9	70.3	14.8
Middle East	31.7	13.4	10.1	-8.3
ASEAN	38.4	20.0	53.6	31.9
NIEs	41.2	32.7	111.0	18.8
China	35.9	30.3	21.9	17.4
Other	64.6	18.1	55.1	4.1
Total	336.1	22.3	442.9	12.0

SOURCE: Ministry of Finance, Foreign Trade Statistics.

advanced technology products, even if Japan is excluded. Table 4-7 shows Japan's overall trading patterns. The United States is still Japan's most important trading partner in terms of imports and exports. However, trade with Asia is growing rapidly for Japan, in particular with the Newly Industrialized Economies (NIEs) of South Korea, Taiwan, Singapore, and Hong Kong and the Association of Southeast Asian Nations (ASEAN)—Indonesia, Thailand, Malaysia, and the Philippines.[10]

[10] Singapore is included as one of the NIEs, but is also a member of ASEAN.

THE POLICY CONTEXT

Although the bulk of U.S.-Japan scientific and technological relationships that affect competitiveness are undertaken in the private sector, official relations form an important part of the context. Until the 1980s, the government-to-government structure for scientific and technological cooperation evolved as an aspect of overall diplomatic relations. As one aspect of efforts to promote democratization in Japan, U.S. occupation authorities cooperated with Japanese scientists to restructure Japanese scientific institutions, with some input from U.S. scientists.[11] The 1961 agreement that set up the U.S.-Japan Committee on Scientific Cooperation emerged from a summit meeting between President Kennedy and Prime Minister Ikeda. During the 1960s and 1970s, a number of U.S.-Japan agreements were reached between specific agencies to conduct or support collaborative research and exchanges in important areas of mutual interests, including energy, space, and life sciences.[12]

During the 1980s, the U.S.-Japan science and technology relationship gradually assumed a higher profile and became more difficult for specialists to manage outside the context of growing economic rivalry. An "umbrella" agreement signed in 1980 was extended rather than renewed in 1985 because of growing pressure on the U.S. side to ensure reciprocal benefits from interactions undertaken through the agreement. After contentious and protracted negotiations, a new agreement was signed in 1988 by President Reagan and Prime Minister Takeshita. It included specific provisions for the treatment of intellectual property, established several new oversight bodies, and called for a balanced and reciprocal relationship in terms of science and technology contributions and benefits. The agreement was renewed without change in 1993. While specific agency agreements continue, the renewed umbrella agreement provides a common basis for oversight and the development of metrics. The U.S.-Japan Framework for a New Economic Partnership, signed by President Clinton and Prime Minister Miyazawa in June 1993, also outlines areas for U.S.-Japan science and technology cooperation in the "Common Agenda" (see Box 4-1).

Science and technology cooperation at the official level, including various agreements and agency-to-agency research collaboration, does not have as great an impact as private-sector cooperation on U.S. or Japanese economic performance or competitiveness. The fact that a great deal of collaborative, precompetitive research in the United States is university based, and therefore easier to access, while comparable work in Japan is often done in proprietary settings, has played a role in the asymmetrical benefits that the two countries derive from cooperation in science and technology.[13] Although some have called for the United States to aggressively pursue reciprocal benefits and quid pro quo in cooperation with Japan and other foreign partners, there is a strong aversion to jeopardizing the openness of U.S. basic research, which is seen as a major

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[11] Scientific Advisory Group to the National Academy of Sciences, *Reorganization of Science and Technology in Japan,* August 1947. For a detailed historical account, see Hideo Yoshikawa and Joanne Kauffman, *Science Has No National Borders: Harry C. Kelly and the Reconstruction of Science and Technology in Postwar Japan* (Cambridge, Mass.: MIT Press, 1994).

[12] See U.S. House of Representatives, Committee on Foreign Affairs and Committee on Science, Space, and Technology, *Science, Technology and American Diplomacy 1994* (Washington, D.C.: U.S. Government Printing Office, 1994). Technology and industrial relationships related to defense have also been extensive and are covered in the report of the parallel Defense Task Force. See National Research Council, *Maximizing U.S. Interests in Science and Technology Relations with Japan: Report of the Defense Task Force* (Washington, D.C.: National Academy Press, 1995).

[13] National Research Council, *Expanding Access to Precompetitive Research in the United States and Japan: Biotechnology and Optoelectronics* (Washington, D.C.: National Academy Press, 1990).

Box 4-1 The U.S.-Japan S&T Agreement and the Common Agenda

U.S.-Japan S&T Agreement

The U.S.-Japan Agreement on Cooperation in Research and Development in Science and Technology (the S&T Agreement or "Umbrella Agreement") was signed by President Reagan and Prime Minister Takeshita in 1988 after several years of sometimes contentious negotiations. The S&T Agreement establishes the policy framework for the overall science and technology relationship between the two countries, superseding a 1980 agreement.[1] It was renewed in 1993 and comes up for renewal again in 1998.

The S&T Agreement states that cooperation should meet four criteria: (1) the United States and Japan have complementary R&D capabilities, resource bases, and centers of excellence, (2) the subject is important to both countries, (3) benefits are distributed equitably, and (4) cooperation accelerates progress in science and technology. The countries commit themselves to provide comparable access to major government-sponsored or -supported programs and exchange of information. The S&T Agreement also seeks to expand dissemination of scientific and technical information and personnel exchanges, particularly opportunities for U.S. scientists and engineers to do research in Japan.

The S&T Agreement established a Joint High Level Committee and Joint Working Level Committee of government officials, and a private-sector Joint High Level Advisory Panel to assess major developments and monitor implementation.

In a recent assessment of U.S.-Japan trade agreements, the American Chamber of Commerce in Japan (ACCJ) rated the S&T Agreement as seven on a scale of one to ten.[2] Over 150 projects have been undertaken through the agreement and dissemination of information has increased significantly. Although some exchange programs have not succeeded, opportunities for U.S. scientists and engineers to perform research in Japan have expanded a great deal (see Chapter 4).

The ACCJ assessment made four recommendations to improve implementation: (1) all pertinent meetings should be posted on a single, common Internet site in both languages, (2) the United States should make requests of Japan based on long-term needs, (3) industry and universities should work more effectively on direct interaction outside government auspices, and (4) the U.S. government should devote more resources to monitoring the agreement and related programs.

Common Agenda

The Common Agenda for Cooperation on Global Perspective was signed by President Clinton and Prime Minister Miyazawa in July 1993 as part of the U.S.-Japan Framework Agreement. The Common Agenda was intended to provide an impetus for expanded U.S.-Japan cooperation to address pressing long-term global problems "such as environmental degradation, population growth, disease prevention, and development of technology and human resources for the future."[3]

Most of the Common Agenda's emphasis is on cooperation in areas such as health and environment. For example, the two countries have embarked on a program to eradicate polio in the Western Pacific and Southeast Asia, with the ultimate goal of eradicating the disease worldwide by 2000. The two governments have launched joint environmental conservation efforts in Indonesia and the Philippines.

Several of the cooperative science and technology programs also address health and environment, in areas such as Arctic research, addressing emerging and re-emerging infectious diseases, earthquake mitigation, and sustainable agriculture. In the area of civil industrial technology, collaboration has been launched in intelligent transport systems, ceramics, technology databases, and bioprocessing.

No formal evaluation of the Common Agenda has been done, but information gathered by the task force during the course of the study indicates that it has been useful in gaining high-level visibility and support in the two governments for joint efforts on global issues.

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[1] *Agreement Between the Government of the United States of America and the Government of Japan on Cooperation in Research and Development in Science and Technology*, June 20, 1988.

[2] American Chamber of Commerce in Japan, *Making Trade Agreements Work*, (Tokyo: ACCJ, 1997).

[3] U.S. Department of State, Bureau of East Asian and Pacific Affairs, "The U.S.-Japan Common Agenda Fact Sheet," August 30, 1996.

strength of the U.S. system. The official structure of agency agreements and government-to-government cooperation could become more important in the future, particularly if Japan follows through on plans to increase support for fundamental research. The agreements could be used to encourage Japan to increase R&D support in critical areas and to ensure that Japan's growing basic research base is open and accessible.[14]

International cooperative science and technology initiatives launched by each country also have raised the visibility of the U.S.-Japan relationship. Several of these initiatives, such as Intelligent Manufacturing Systems and the Superconducting Supercollider, were described in Chapters 2 and 3. Although international sharing of risks and resources in large science and technology programs has a compelling logic, the mixed record of these efforts by the United States and Japan illustrates the inherent difficulty of reconciling the interests of various participant countries. In particular, some believe that the difficulties of the U.S.-initiated projects resulted from lack of consultation with potential international partners early in the planning process.[15] These difficulties appear to rise with the cost, scale, and visibility of the project.

A final aspect of the evolution of the official relationship has been a series of initiatives and programs under the auspices of one or both governments to rectify the large imbalances in the flows of technically trained personnel and scientific and technical information. The task force had an opportunity to learn about these programs at several of its meetings.

Exchanges of Scientific and Engineering Personnel

Growing awareness of Japan's technological prowess and concern over continuing wide imbalances in the flow of scientists and engineers between the two countries led to a number of new programs and initiatives since the early 1980s. These initiatives have been aimed at

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[14] These issues are discussed in National Research Council, *Strategies for Achieving U.S. Objectives in Science and Technology Relations with Japan: Report of a Workshop* (Washington, D.C.: National Academy Press, 1996).

[15] The task force endorses this statement from William J. Clinton and Albert Gore, Jr., *Science in the National Interest,* Office of Science and Technology Policy, 1994, p. 13: "We must enter international collaborations with clear responsibilities and secure commitments from each partner. For this, we must establish with the Congress mechanisms for prioritizing, committing to, and then sustaining long term support for large projects. This need applies equally well to large American projects with multi-year time scales."

increasing opportunities for American researchers and engineers to visit and work in Japan and expanding language and cultural training programs so that American technical personnel can derive maximum benefit from these interactions.

Through a workshop held in 1994 and additional follow up research, the task force gathered information to assess the overall need and effectiveness of personnel training and exchange programs. Although this broad assessment cites examples, the purpose was not to evaluate specific programs but to develop conclusions on the broad U.S. effort, with a view toward long-term national needs.

A range of programs trains U.S. scientists and engineers in Japanese language and sends them to Japan. A report by the National Science Foundation in 1994 included all known noncorporate programs to send American researchers to Japan, primarily in science and technology.[16] In the 1993-1994 U.S. fiscal year, listed programs supported 809 Americans to visit Japan for one week to a year or more. Nearly half of these were for periods of three months or longer, with one fourth staying for a year or more.

MIT-Japan Program

Established in 1981, this is the longest running program to train U.S. scientists and engineers in Japanese language and to provide research opportunities in Japan. Most of the students participate in the program at the graduate level. The program requires two years of language training, followed by an internship that generally lasts for a year. Most of the interns go to Japanese companies, although some go to universities or government laboratories.

The MIT-Japan Program is supported by several sources, including private foundations, corporate members, and the Air Force Office of Scientific Research-managed Japanese Industry and Technology Management Training Program (JITMTP, see below). For the internships, the Japanese hosts provide considerable in-kind support (room and board).

Of the 371 program alumni from the 1981-1996 period who responded to a survey earlier this year, 179 worked in areas that were Japan-related.[17] From discussions during the 1994 workshop organized by the task force, it is clear that many of these graduates are doing valuable work for U.S. organizations in their dealings with Japan.[18]

The MIT-Japan Program is a good illustration of the task force's main points on this issue: (1) federal support is well leveraged with private and Japanese support, and (2) U.S. industry clearly utilizes a significant number of Japan-capable scientists and engineers, although the demand does not amount to thousands per year.

AFOSR-JITMTP

This program was launched in 1991. In most years it has divided $10 million into 4 two year competitive grants. For 1996-1997, the money has come through the Defense Advanced Research Projects Agency budget, but it is still managed by AFOSR.

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[16] National Science Foundation Tokyo Office, "Current Status of Programs to Support American Researchers in Japan," Report Memorandum #94-7, November 1994.

[17] Communication from the MIT-Japan Program, May 1997.

[18] Specific case examples are included in Patricia Gercik, *On Track With the Japanese* (New York: Kodansha America, 1992)

The NRC's Manufacturing Studies Board conducted an assessment of the program which was released in 1994.[19] The report was favorable overall, and contained suggestions for more effective program management. It also recommended that the government provide stable five year funding to grantees, in order to improve effectiveness.

JITMTP grants support a range of activities, including research, internships, shorter stays, development of technically-oriented language curricula, and information access programs. According to the NSF report, the grantees send several hundred researchers to Japan per year. The programs have various approaches on issues such as whether students are required to study Japanese language.

NSF Programs

Many of the U.S. government funded exchanges are managed by NSF. These mainly send academic scientists and engineers to Japan for visits of one week to over a year. Several programs utilize Japanese funding. One very popular program is the Tsukuba Summer Institute that NSF runs jointly with the National Institutes of Health. Under the program 40-50 Ph.D. candidates spend the summer at Japanese government labs.

As with the MIT-Japan program, the NSF experience shows that there is considerable interest in research opportunities in Japan among U.S. scientists and engineers, particularly when programs are structured so that large opportunity costs are not incurred in order to participate. In addition to NSF programs, the Japanese government funds and manages several programs directly.

Manufacturing Technology Fellowship Program

This is a joint program between MITI and the Department of Commerce (DOC) launched in 1993 following a visit by Vice President Quayle. The purpose is to place U.S. engineers in Japanese manufacturing environments for one year internships. The fellows participated in a one month orientation program before traveling to Japan.

Although it was contemplated that 50-100 fellows per year would go through the program, it has not been able to fulfill those expectations. The current year is the final one for DOC funding. The major problems included difficulties in making arrangements on the Japanese side to make the program more attractive to U.S. companies, and the leaner organizational approach of U.S. companies. The American Society for Engineering Education is trying to continue the program on a private basis.

Lessons Learned

The task force draws several lessons from this experience. First, the investment by the U.S. government in direct support of American researchers and engineers in Japan appears to be very cost effective. A large number of science and technology personnel are influenced by a relatively small U.S. government investment.[20]

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[19] National Research Council, *Learning from Japan: Improving Knowledge of Japanese Technology Management Practices* (Washington, D.C.: National Academy Press, 1994).

[20] Precise figures are not available, but discussions at the 1994 workshop indicated that appropriated U.S. government funding for long-term stays was roughly $1.5 million annually. In addition, the U.S. government receives approximately $1 million annually from Japan's Center for Global Partnership, and American researchers selected by U.S. government agencies receive approximately $2.2 million annually through the fellowship programs of the Science

A second insight of the task force is that the expectations of some observers and participants may be unrealistically focused on short term impacts. A number of workshop participants noted that the full value of the Japan experience is unlikely to be realized in the first job after returning from Japan. A number of alumni who participated in the 1994 workshop indicated that the value of their Japan experience was eventually put to good use after several years of employment, through a combination of self-motivation and taking advantage of opportunities within the organization.

Clearly, several programs have not met demand expectations, such as the Manufacturing Technology Fellowships, and funding has been cut. In the short term, this ensures that the government does not expend resources where there is a small apparent demand, but it does foreclose the possibility that the program could have been restructured to be more attractive to U.S. industry.

In short, the task force concludes based on its examination that there is a continuing demand and need for Japan-trained scientists and engineers, and that the modest U.S. government investments in this area are effective and well leveraged. The task force believes that the long term issues are particularly important to bear in mind. With Japan increasing its investments in basic research, the need for U.S. capabilities to access Japanese scientific and technological know-how, particularly human resources, is also likely to increase.

Japan represents a special case among countries with which the United States has significant science and engineering ties. Compared with the flow of scientists and engineers from China and Korea, many of whom stay to work for U.S. companies and organizations after receiving advanced training in the United States, a much larger percentage of Japanese scientists and engineers who receive training here return to Japan. As opportunities improve in their home countries, the percentage of non-Japanese Asian scientists and engineers who return is rising.

The United States is unlikely to build the necessary human resources in this area without public support and incentives. Particularly when combined with the rigors of pursuing a science and engineering curriculum, the difficulty of learning the Japanese language and cultural skills discourages students from making the substantial commitment required to develop the requisite skills on their own. Because of the relatively high rate of job mobility in the United States and other factors, U.S. industry employers are also reluctant to invest in Japan-related language and cultural training for their employees. Although some university programs can show increasing industry involvement and support, it is unlikely that the private sector will make investments in skills and expertise that will only pay off over the long term and that may not be appropriable by individual companies.

In addition to confirming the overall value of Japan-related technical personnel training and internship programs, the task force discussed and considered various specific issues related to their orientation and management. One question is whether university-based or government exchange programs should be focused on specific technical areas or on more general country expertise. Targeting specific technical areas might help participants maximize the value of their experience and develop expertise of interest to American industry. On the other hand, a broader experience can provide a better foundation for participants' long-term careers. Perhaps a variety of approaches, as are supported now through the AFOSR-supported programs and by other government efforts, can be effective and mutually reinforcing.

Another management issue considered by the task force is the development of follow-up and evaluation efforts on the part of programs. Although the modest funding levels of these programs

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and Technology Agency and the Ministry of Education. As noted in discussion of the MIT-Japan Program, in some cases fellowships and internships leverage in-kind support from Japanese hosts, and additional support from private foundations and corporate sponsors.

do not justify extensive follow-up and evaluation efforts, significant value could come from relatively simple follow-up activities such as keeping track of alumni of the programs and performing periodic surveys on their experiences and subsequent career paths.

Utilization of Japanese Scientific and Technical Information

A focus on efforts to improve U.S. access to and utilization of Japanese scientific and technical information (JSTI) also increased during the early 1980s. In 1986 Congress passed the Japan Technical Literature Act, and the Japan Technology Program at the U.S. Department of Commerce was established to coordinate collection and translation efforts.[21] Information access became a topic for ongoing bilateral consultations under the U.S.-Japan Science and Technology Agreement. A series of joint conferences held by the Japan Information Center for Science and Technology and the National Technical Information Service have publicized these programs and served as a continuing forum for exchange on JSTI-related issues. The task force examined a number of public and private efforts to obtain and disseminate JSTI, trends in U.S. industry needs, and possible new approaches.

One problem in assessing U.S. industry utilization of JSTI is the fact that systematic surveys and data are lacking. Any assessment, therefore, must rely heavily on anecdotal information. Still, in discussions with the task force both large and small U.S. companies reported concrete benefits from their JSTI collection and utilization activities. One clear message is that U.S. companies have a variety of motivations and strategies for accessing and using JSTI. In order for U.S. policies to have an impact, the diversity of U.S. industry needs and capabilities must be taken into account. At the same time, given the current environment of severely constrained resources for corporate R&D activities, JSTI-related activities must be cost effective and have a highly focused technical or business rationale. Finally, the rapid expansion of access to the Internet is changing the way that organizations and individual researchers access and use information.

Large U.S. companies employ a variety of strategies for accessing and utilizing JSTI. The corporate R&D division of one large U.S. conglomerate, for example, maintains a permanent staff of three to four people in Japan to access information and facilitate technical interactions between U.S.-based technical staff and a variety of Japanese institutions, including companies, universities, and government laboratories. In the view of this company the most useful insights into Japanese technical developments are gained from actually engaging in collaborative R&D. Another American multinational in the computer industry has a specialized Japanese staff that monitors patent applications and technical papers. This helps the company stay abreast of what its competitors are doing and contributes to its own Japanese patenting activities. Commercial newsletters and translation services also are frequently utilized. However, the scale and quality of in-house JSTI programs of U.S. companies vary a great deal.[22]

Small U.S. companies have special needs and concerns related to JSTI. Small companies just becoming aware of their needs for JSTI may waste time and resources, since they generally do not possess specialized Japan expertise and may lack knowledge of the extensive U.S. resources that are available. Despite these barriers, participants in a discussion organized by the Competitiveness Task Force observed that most small U.S. high-technology companies seriously tackling the challenge of accessing the Japanese market find that they need to develop a focus on

[21] The Japan Technology Program is now part of the Asia Pacific Technology Program.

[22] In addition to information programs, several large U.S. companies, such as Motorola, Kodak, and AT&T, have established a policy presence in Japan in recent years, in light of the significant impact that changes in Japanese policies will have on market participation prospects.

Japanese information access. Small companies seeking to break into the Japanese market often are able to build effective mechanisms for accessing information over time but report that more complete and timely information is needed in some areas. This is particularly true for patent-related information. This is a crucial issue, since success or failure in obtaining intellectual property protection in Japan has a major impact on the overall market access prospects for small high-technology companies.[23]

Despite the large volume of JSTI available in various forms, task force discussions revealed that it is still difficult for both large and small U.S. companies to obtain answers to some specific questions quickly and easily. For example, a U.S. biotechnology company researched the question of how many biotechnology companies there are in Japan and came up with a wide range of answers. The company also reported problems in locating information about the incidence and demographics of various diseases and medical conditions in Japan—information that is readily available in the United States. Legal and regulatory information also can be difficult to obtain.

Despite growing interest in JSTI and a number of initiatives over the past decade to improve U.S. capabilities to collect, translate, and disseminate such information, developing new capabilities that successfully fill user needs has not been a simple process. Scan C2C, a commercial enterprise established to collect and disseminate JSTI, was ultimately unable to secure a sustainable business base. Some efforts supported by the U.S. and Japanese governments, such as computer terminal access to databases of the Japan Information Center for Science and Technology, have not been extensively utilized. A news report in 1995 stated that a new collaborative effort by Stanford University and Nippon Telephone and Telegraph (NTT) to put Japanese information on the Internet was enabling NTT to learn a great deal about software and the Internet but had made only limited progress toward facilitating access to Japanese information.[24] A General Accounting Office report of several years ago faulted overall U.S. government efforts for being too concentrated in military agencies and not being well connected with commercial industries and technologies.[25]

Although the U.S. public and private sectors do not expend nearly the resources that Japanese organizations such as the Japan External Trade Organization or general trading companies do to collect and disseminate foreign science and technology information, and interest in JSTI has not led to the development of large markets, the United States does possess a number of institutions and capabilities that collectively fill the needs of a wide variety of general users of JSTI. Among U.S. government agencies, the Commerce Department's Office of Technology Policy and the Japan Technology Program play a coordinating and policy role that includes tracking the foreign science and technology information activities of other agencies and the private sector.[26] The Japan Technology Evaluation Center (JTEC), which undertakes expert assessments of Japanese technologies for various federal sponsors, has spawned offshoot programs that evaluate technological developments in Europe, the former Soviet Union, and

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[23] In what the task force believes to be a positive and important step, the Japan Patent Office has launched an experimental database of patent publication abstracts available on the World Wide Web. Entries include English and Japanese versions of abstracts from patent applications that are published eighteen months after filing.

[24] See Michael Zielenziger, "Dream Team? U.S. Researchers Hook Up with NTT," *Far Eastern Economic Review,* May 4, 1995, pp. 60-61. Stanford reports that as the Japan Window project has proceeded much more Japanese information has been made available, and that NTT has made important technical contributions. Communication from Stanford University, May 1997.

[25] U.S. General Accounting Office, *Collection and Dissemination of Japanese Information Can Be Improved* (Washington, D.C.: U.S. Government Printing Office, 1993).

[26] See U.S. Department of Commerce, Office of Technology Policy, *Foreign Science and Technology Information Sources,* July 1996.

elsewhere. The Japan Documentation Center (JDC) of the Library of Congress provides access to a range of sources, including unpublished, or "gray" literature. The Asia Technology Information Program, which is supported by federal and private sponsors, provides free abstracts of its proprietary reports over the Internet. The National Science Foundation's Tokyo Office publishes occasional report memoranda on various aspects of Japan's science and technology policies. R&D consortia such as the Microelectronics and Computer Technology Corporation, nonprofits such as the Japan Information Access Project, industry associations such as the American Electronics Association and several of the Japan Industrial Technology Management Training programs provide ongoing information collection, analysis, and dissemination to their members.

The task force believes that collection and dissemination of JSTI and improved utilization are important national tasks where the public and private sectors have essential roles to play. The task force identified three U.S. priorities for improving access to and utilization of JSTI.

First, it is important to maintain public support for government programs such as Japan Technology Program, JDC, JTEC, and others that focus on Japanese and Asian technology information and analysis and to make as much of the resulting information as possible available to the public. These are not expensive activities, and they leverage activities and programs that the government will be undertaking in any case. Government and other programs that provide JSTI to the public at little or no charge may also play a positive role by pressuring proprietary services to perform at a higher standard.

One positive recent example is the Machine Translation Center for Japanese Science and Technology Literature at the U.S. Department of Commerce. The service is provided at no charge in cooperation with the Japan Science and Technology Corporation. Only raw machine translation output is provided. Response to the service, particularly from industry, has been very favorable. Many of the documents submitted for translation are patent filings. The machine translation allows the company to judge whether a document is important enough to be hand translated.[27]

Second, public and private organizations involved with JSTI should focus on utilizing advances in technology to ensure that the organizations engaged in these efforts are linked to the extent possible and to increase access to information for small companies and individual researchers. A significant amount of progress in this area has been made in the past several years, and most of the prominent programs make significant amounts of information available electronically.

Finally, there is a continuing need to eliminate barriers to timely access to a range of important and potentially useful Japanese information. Although some barriers reflect inherent characteristics of Japan's "information culture," others appear to be amenable to change through Japanese government policy changes that could be sought through the U.S.-Japan Science and Technology Agreement. One possible goal would be to make all Japanese government reports available on-line immediately in Japanese. Although much of this government information (laws, regulations, gray literature) is not directly related to science and technology, timely access could enable U.S. companies to participate in the Japanese market more effectively. In some cases the Japanese government could make JSTI more accessible as well. For example, some large databases are only accessible electronically during business hours in Japan, which is inconvenient for many potential U.S. users.

[27] Communication from the U.S. Department of Commerce, March 1997.

5
U.S.-Japan Technology and Competitiveness Trends in Key Industries

SUMMARY POINTS

• *The task force examined technology and competitiveness trends in the United States and Japan in several key industries. These case descriptions are based on discussions with industry experts at the January 1995 task force meeting and have been supplemented with background research.*

• *In recent years U.S. companies in a number of industries have improved their competitive performance. In automobiles, U.S. companies have responded to pressure from Japanese competitors, and Japanese investments have contributed to overall U.S. capabilities. In biotechnology and health care, a strong fundamental research base and a financial structure enabling commercialization of technologies through the formation of new companies have been the most important factors. In semiconductor manufacturing equipment, a resurgence of the U.S. semiconductor device industry and improved cooperation between companies and with government have played major roles. In information industries, a strong research base and the dynamic U.S. market have enabled U.S. companies to play a leading role in setting de facto standards and architectures.*

• *Japanese companies are still major competitors, and Japanese government and industry are still pursuing policies designed to attain global technological and market leadership. But changes are occurring as well. Japanese companies are more open to reciprocal relationships. Japanese markets are somewhat more open, particularly in consumer products. However, U.S.-Japan differences in regulatory approaches, intellectual property protection, private-sector business practices, and other areas are likely to persist. How quickly opportunities to participate in Japanese and Asian high-technology markets expand will play a major role in determining whether the United States derives maximum economic benefit from science and technology cooperation.*

AUTOMOBILES

Besides being a significant contributor to the U.S. and Japanese economies as the largest employer among manufacturing sectors, the automobile industry is increasingly a high-technology sector, owing to its growing utilization of electronics, advanced materials, and information systems. If production and engineering systems are included in the definition of "technology," it is clear that a great deal of U.S.-Japan technological interaction (competition, learning, technology transfer through direct investment) has occurred over the years and continues in this industry.

Market Access Asymmetries

The competitiveness setbacks suffered by the U.S. auto industry and the corresponding gains by Japanese manufacturers during the 1970s and 1980s have been extensively studied and documented.[1] One advantage enjoyed by the Japanese auto industry from the early postwar rebuilding period is the asymmetry in market access between Japan and other major auto-producing and auto-consuming countries, most notably the United States. Although Japan committed to deregulate foreign capital and exchange controls upon joining the Organization for Economic Cooperation and Development and the International Monetary Fund in 1964, moves toward capital liberalization did not begin until the late 1960s.[2] By this time the U.S. Big Three automakers were very interested in entering the Japanese market, but the Ministry of International Trade and Industry (MITI) and most of the domestic industry argued that the Japanese industry was still too weak and fragmented. Resistance by several second-tier firms to MITI's consolidation plan for the industry led to a partial opening. Chrysler and General Motors took minority equity stakes in Mitsubishi Motors and Isuzu. Ford purchased a minority share in Mazda in the late 1970s.[3]

These investments did not lead to significant market participation by the Big Three. The Japanese industry had already built considerable competitive strength in its protected domestic market. Before the U.S. companies could devote much effort to penetrating the Japanese market, Japanese autos were making considerable headway in the United States.

Japanese Industry Advantages

The Japanese auto industry's gains during the 1970s and 1980s were made possible by significant advantages it enjoyed over the U.S. industry in three areas.[4] The first advantage was in management. General Motors and Ford were (and still are) the largest manufacturing companies in the world. Their competitive environment during the post-World War II period allowed them to focus on the lucrative U.S. market and on each other as competitors. This led to complacency and the development of organizational structures and management styles that were ill suited to the competitive environment that emerged in the U.S. market and globally in the 1970s. Relations between manufacturers and external suppliers, labor and management, and industry and government were at arms length and often adversarial.

During the late 1940s, the Japanese auto industry experienced severe business conditions and fierce labor disputes and nearly collapsed. Survival was ensured by U.S. military procurement of Japanese vehicles during the Korean War. With rapid recovery in the overall economy, Japanese companies were able to step in and meet rising demand, developing vehicle characteristics (such as smaller size) suited to the domestic market. During the industry's period of stress, companies such as Toyota became less vertically integrated and instead made greater use of external, but

[1] For example, the automobile case study that appears in Michael L. Dertouzos, Richard K. Lester, and Robert M. Solow, *Made in America: Regaining the Productive Edge* (Cambridge, Mass.: The MIT Press, 1989), pp. 171-187.

[2] See Mark Mason, *American Multinationals and Japan* (Cambridge, Mass.: Harvard University Press, 1992), p. 201.

[3] There is considerable debate over how interested the Big Three were in reentering Japan in the 1940s and 1950s. It is also argued that the U.S. auto industry investments in Japan in the late 1960s and early 1970s were motivated largely by a desire to source small cars from Japan for the U.S. market. Phyllis A. Genther, *A History of Japan's Government-Business Relationship: The Passenger Car Industry* (Ann Arbor, Mich.: Center for Japanese Studies, 1990).

[4] Much of this section is drawn from the presentation of Michael Smitka at the meeting of the Competitiveness Task Force held January 12-13, 1995.

often affiliated, suppliers as a cheaper alternative to direct control of the supplier chain.[5] This approach, taken out of necessity, led to the development of a more flexible auto production system, which has become popularly known as the Toyota Production System or "lean manufacturing." By the late 1970s, the manufacturing practices associated with this system ensured higher quality and productivity than the production systems of U.S. manufacturers. The quality difference was critical in allowing Japanese automakers to maintain and expand their inroads into the U.S. market during the 1980s, as consumers who had good experiences with their first Japanese cars developed strong loyalty.

A second advantage enjoyed by Japanese auto companies was in cost structure. Lower Japanese labor costs relative to the United States and the fact that wage increases lagged behind productivity gains gave Japanese auto companies a significant edge by the late 1970s. The gap was widened by a strengthening of the dollar in the early 1980s.

Several serendipitous trends in the global economy during the 1970s and 1980s also were favorable to the Japanese auto industry and hindered U.S. producers. The rapid rise in oil prices during the 1970s led to greater demand for small cars in the U.S. market, which Japanese companies were better equipped to fill. Simultaneous pressure to meet new environmental standards and increase fuel economy strained the engineering capabilities of the Big Three and contributed to declining quality and performance.

These conditions set the stage for the rapid gains made by Japanese auto companies in the U.S. market beginning in the late 1970s. The U.S. recession of the early 1980s combined with market share losses put severe stress on U.S. automakers. With the imposition of a voluntary restraint agreement in the early 1980s that limited the number of Japanese autos exported to the United States, Japanese manufacturers moved toward setting up U.S. production facilities. Table 5-1 shows trends in world auto production.

TABLE 5-1 Motor Vehicle Production

	1977	1982	1987	1992
World total (millions of vehicles)	40.9	36.1	45.9	47.7
North America	14.7 (36%)	8.7 (24%)	12.9 (28%)	12.7 (27%)
Europe	15.9 (34%)	14.8 (41%)	17.5 (38%)	17.5 (37%)
Asia	8.8 (22%)	11.2 (31%)	14.0 (31%)	14.6 (31%)
Japan	8.5 (21%)	10.7 (30%)	12.2 (27%)	12.5 (26%)
Korea	0	0.2	1.0	1.7
Other Asia	0.3	0.3	0.8	0.4[a]
Rest of the world	1.5	1.4	1.5	2.9

[a] The 1992 figure does not include China.

SOURCE: Compiled by the American Automobile Manufacturers Association.

[5] Japan's auto industry provides support both for those who argue that Japanese industrial policy was a key to industrial development, and those who argue that it had a marginal impact. For an account of business-government relations in Japan's auto industry, see Genther, op. cit. Chapter 5 deals with the development of the Japanese auto parts industry.

U.S. Resurgence

Over the past 15 years or so, the U.S. auto industry has been engaged in the sometimes slow and difficult effort of responding to Japanese competition and closing these gaps. Prompted by competitive pressure and, some have asserted, the demonstration effect of Japanese manufacturing operations in the United States, U.S. automakers and suppliers have made significant strides in manufacturing and product development performance.[6] In the mid-1980s, the dollar depreciated significantly against the yen, and another large rise in the value of the yen occurred in 1993-1994. These currency trends reversed the cost advantage that had been enjoyed by vehicles built in Japan.

Trends external to the industry also contributed to a U.S. resurgence. The upward trend in oil prices was reversed in the mid-1980s, and oil has been moderately priced since that time. This has dulled the appetite of U.S. consumers for smaller vehicles and sparked increasing demand for larger vehicles such as minivans, light trucks, and sport utility vehicles, categories that U.S. companies pioneered and are better positioned than the Japanese to serve.

Over the 1993-1994 period, U.S. automakers reaped the benefits of these accumulated favorable trends, as rising demand produced record profits and market share gains. Chrysler's resurgence has been particularly conspicuous, while GM's market share has continued at a level far below that of the mid-1970s. At the same time, the Japanese auto industry suffered from sluggish demand in the domestic market and cost pressure on exports of vehicles and parts to the United States. Most Japanese automakers reported losses during this period. Some of the second-tier Japanese producers, such as Mazda, have suffered a great deal during the downturn.[7]

More recently, the Japanese vehicle market has recovered somewhat, the dollar appreciated considerably during 1995 and 1996, and conditions for Japanese automakers have stabilized and improved. Even during the 1993-1994 period, Japanese automakers as a whole did not lose a significant amount of market share in the United States, particularly in passenger cars. Transplant production has played an important role.

Future Technology and Competitiveness Issues

The main issues for the world auto industry over the coming decade are (1) continuous improvement in manufacturing and product development performance to deliver value to customers—a fundamental competitive necessity for vehicle manufacturers and suppliers; (2) achieving effective participation in emerging markets, particularly in Asia, while balancing related technology and production transfer demands—a key determinant of growth; and (3) companies and national industries may create competitive advantage for the twenty-first century based on new technologies such as "intelligent" vehicles and highways. The Japanese and U.S. auto industries, and individual companies, bring different strengths to this competition.

Manufacturing and Product Development

High-quality manufacturing and effective product development performance are fundamental competitive necessities for auto manufacturers seeking to establish and maintain leading

[6] Wellford W. Wilms, Alan J. Hardcastle, and Deone M. Zell, "Cultural Transformation at NUMMI," *Sloan Management Review,* Fall 1994, documents the positive impact of combining Japanese and U.S. management approaches at the plant level.

[7] "Matsuda, kokunai baibai haisui no jin" (Mazda's Last Stand in the Domestic Market), *Nihon Keizai Shimbun,* October 13, 1995, p. 11.

positions in the most sophisticated and profitable markets. Although the top Japanese companies remain the world benchmarks in these areas, U.S. companies have made considerable strides in recent years.[8] During the 1990s, for example, Chrysler adapted a number of lessons from Japanese "best practices" and improved its product development process considerably.

One of the most significant challenges faced by the Japanese auto industry in recent years has been to maintain manufacturing and product development excellence while reducing costs. Although the yen has stabilized and weakened recently, cost pressure has been acute, particularly in the U.S. market for cars exported from Japan. The Japanese industry has been aggressively adjusting to these imperatives. Shifting production to the United States, Asia, and elsewhere is one approach. Japanese companies have made modest efforts to procure components for their U.S.-assembled vehicles in Asia in order to cut costs. Table 5-2 shows several examples. For Japanese manufacturers and suppliers to retain long-term competitive advantage, it will be necessary to globalize manufacturing while maintaining productivity and quality.

Japanese companies also have sought to ensure the continued competitiveness of domestic operations by increasing the reusability of parts, cutting management staff, and in some cases slowing new product introduction cycles.[9] Japanese automakers are encouraging their suppliers to sell to a broader base of customers to support higher volumes and lower costs, encouraging weaker suppliers to merge and increasing purchases from nontraditional suppliers.

Relationships between manufacturers and suppliers are critical to overall manufacturing and product development performance. Automobile value added is likely to come increasingly from the incorporation of electronics, new materials, and other innovations originating outside the automobile manufacturers themselves.[10]

TABLE 5-2 Examples of Asian Parts Utilized by Japanese Automakers in U.S.-Built Vehicles

Company	Part	Country
Toyota	Cylinder block	Thailand
Honda	Cast and forged components	China[a]
Mitsubishi	Press components	Korea
Mazda	Radiator	Korea

[a] Under consideration.
SOURCE: *Nihon Keizai Shimbun*, September 15, 1995, p. 11.

[8] Kim B. Clark and Takahiro Fujimoto, *Product Development Performance: Strategy, Organization and Management in the World Auto Industry* (Boston, Mass.: Harvard Business School Press, 1991), describes the elements of effective product development and documents the superiority of Japanese management practices.

[9] Gerald Conover, presentation to the Competitiveness Task Force, January 12, 1995. See U.S. Department of Commerce, Market Research Report, "Japan-Auto Parts Development Plan," July 21, 1994. This report describes new cooperation, even between bitter traditional rivals, to develop common parts for the good of the entire Japanese auto industry.

[10] Ulrike W. Hodges and Rob van Tulder, *The Chemistry of Dependence: Cars, Chemicals and Technological Change in the United States, Germany and Japan* (Berkeley Roundtable on the International Economy Working Paper 69, November 1994).

The U.S. supplier base is characterized by a relatively small number of large, technologically sophisticated companies that compete on a global basis and smaller second- and third-tier suppliers. In the decade or so since it entered the automotive seating business, Milwaukee-based Johnson Controls, Inc. (JCI) has established itself as a leading representative of the first-tier supplier group.[11] JCI supplies each of the U.S. Big Three automakers with seats and supplies almost all of Toyota's vehicle programs outside Japan.[12] JCI credits its relationship with Toyota with helping to hone its manufacturing and product development capabilities. Since being selected to supply seats to NUMMI, the Toyota-GM joint venture, JCI has worked to incorporate the lessons of continuous improvement into its overall manufacturing operations. JCI has also contributed to moves on the part of U.S. auto manufacturers, most notably Chrysler, toward adapting Japanese methods of product development that involve greater technological and engineering responsibilities for first-tier suppliers.[13] For the future, JCI is focusing on incorporating higher levels of proprietary technology into its automotive seating systems and leveraging its capabilities to boost its presence outside the United States. It recently acquired Prince, an auto supplier with strong electronics technology.

Although a number of U.S. auto manufacturers and suppliers are pursuing continuous improvements in manufacturing and product development by adapting Japanese practices and have achieved world-class performance, many others, particularly smaller suppliers, have not yet implemented these approaches successfully. Recent studies indicate that Japanese auto suppliers remain the most productive and deliver the highest quality.[14]

Global Strategies and Approaches to Rapidly Growing Asian Markets

Tapping rapidly growing markets in Asia will be key to future growth for U.S. and Japanese automakers. Asia has long been a secondary overseas market focus (after the United States) for a number of Japanese auto companies. These efforts have given Toyota, Mitsubishi, and others a head start in several of the most important markets.[15] In recent years, Japanese manufacturers have increased their investments and marketing activities in Asia. For example, Toyota hopes to build a leadership position in the rapidly growing Asian auto market through the development of its "Asia car."[16]

Japanese auto suppliers belonging to a particular group or *keiretsu* often invest in Asia as a group. For example, several of Toyota's suppliers have announced plans to launch manufacturing

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[11] In 1994, sales of JCI's automotive segment were about $2.9 billion, or about 42 percent of the corporate total. See *Hoover's Company Profile Database* (Austin, Tex.: The Reference Press, 1996).

[12] Larry Hagood, from his presentation to the Competitiveness Task Force, January 12, 1995.

[13] Rajan R. Kamath and Jeffrey K. Liker, "A Second Look at Japanese Product Development," *Harvard Business Review*, November-December 1994, p. 170.

[14] Andersen Consulting, Cardiff Business School, and the University of Cambridge, *Worldwide Manufacturing Competitiveness Study: The Second Lean Enterprise Report,* 1995, as reported in National Center for Manufacturing Sciences, *Focus,* July 1995.

[15] Japanese companies have proven more willing to comply "with national local content programs initiated in the early 1970s." See Richard F. Doner, "Japanese Automotive Production Networks in Asia," in Eileen Doherty, ed., *Japanese Investment in Asia* (Berkeley, Calif.: The Asia Foundation and Berkeley Roundtable on the International Economy, 1995), p. 101.

[16] "Ajia ka: Toyota, 22 man dai ni" (Asia Car: Toyota Plans Production of 220,000), *Nihon Keizai Shimbun,* August 20, 1995, p. 1.

facilities in China.[17] In September 1995, 70 Japanese auto suppliers affiliated with Nissan announced plans to transfer technology to counterparts in Korea's Samsung group.[18]

Although it had appeared until recently that most of the U.S. auto industry had "written off" Asian markets besides China, the Big Three and a number of major suppliers are now pursuing more aggressive initiatives. With trade barriers in Asia likely to fall in coming years, concerns about tying up large fixed investments to serve several small segmented markets are receding. Leveraging their recent success in the domestic U.S. market and a desire on the part of some Asian nations to balance an already large Japanese direct investment presence, it appears much less likely at this writing that U.S.-based companies will be "left behind" in Asia.

During 1995, U.S. automakers stepped up plans to increase their presence in Asia. Ford, which has 11 existing plants and engineering sites in Asia, announced plans to invest $53 million in two component plants in Thailand.[19] China's leading automaker chose General Motors for a $1 billion venture, and as of this writing GM was in the process of choosing a location for a large manufacturing operation in Southeast Asia. Chrysler, which has operations to assemble Jeep Cherokees from kits in Thailand, Malaysia, and Indonesia, is considering plans to build a small affordable car for Asian markets such as Vietnam and India.[20] A number of U.S.-based auto suppliers also have announced various investment and joint venture plans in China.[21]

Although Japanese and U.S.-based companies are taking somewhat different approaches to investment and market participation in Asia, they will face similar challenges in managing technology transfer in order to ensure a long-term presence and avoid aiding potential competitors. Willingness to transfer technology was reportedly a factor in China's decision to choose GM as the foreign partner for its sedan venture.[22] Proton, the Malaysian auto company, consistently requests expanded technology transfer from its Japanese partner, Mitsubishi Motors.[23]

Access to the Japanese market remains an issue for U.S. automakers and suppliers. Recently, there have been a number of indications that the Japanese market is becoming more open to imports. Sales of imported vehicles have grown rapidly in Japan in recent years, albeit from a very small base, partly due to the cost advantage enjoyed by imports.[24] In 1995 the United States and Japan reached agreement on measures to increase sales of imported autos and auto parts in Japan after contentious negotiations.

The access problems of foreign auto suppliers are somewhat different than those of vehicle producers.[25] Access to the Japanese replacement-parts market would likely be improved through

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[17] "Aitsugi Chugoku shinshutsu" (Advancing into China One After Another), *Nihon Keizai Shimbun,* August 1, 1995, p. 11

[18] "Sansei gurupu ni gijutsu kyoyo" (Furnishing Technology to the Samsung Group), *Nihon Keizai Shimbun,* September 13, 1995, p. 15.

[19] "U.S. car makers are investing heavily in Asia," *The Wall Street Journal,* January 25, 1996, p. A4.

[20] "Chrysler Considering Building a Small Car for Markets in Asia," *The Wall Street Journal,* October 16, 1995, p. A4.

[21] "Tai-Chu toshi o kasoku" (Chinese Investment Accelerates), *Nihon Keizai Shimbun,* December 27, 1995, p. 7.

[22] "Price of Entry into China Rises Sharply: U.S. Firms Face Growing Pressure to Transfer Technology," *The Wall Street Journal,* December 19, 1995, p. A14.

[23] "Mitsubishi Jiko ni yosei" (Demand to Mitsubishi Motors), *Nihon Keizai Shimbun,* November 22, 1995, p. 1.

[24] In 1995, Japan's imported car sales reached 388,162, representing a 29 percent rise over 1994. The 10.2 percent share of the market held by imports represents a near doubling in two years. German models represented 43.1 percent of import sales and U.S. models 33.9 percent. Japan Automobile Importers' Association figures reported in *The Washington Post,* January 11, 1996, p. D10.

[25] The U.S. government still considers implementation of the 1995 auto agreement to be a major issue, particularly in auto parts. See U.S. Trade Representative, *National Trade Estimate 1997* (Washington, D.C.: U.S. Government Printing Office, 1997).

the elimination or easing of several specific regulatory requirements. In the original-equipment market, however, Japanese business practices may continue to act as a ceiling on foreign participation, regardless of price and quality considerations.[26] Even in cases where Japanese automakers and first-tier suppliers purchase foreign-made components for vehicles intended for export or made in U.S. transplant facilities, they are reluctant to utilize the same parts for autos made and sold in Japan. Even during the 1994-1995 period, when many Japanese automakers were losing money and were eager to cut costs, proposals by U.S. suppliers that would have led to significant cost savings were reportedly rebuffed.[27]

Although many U.S. parts makers will continue to be largely shut out of the Japanese domestic OEM market, the experience of JCI and other U.S. suppliers indicates that a focus on supplying the production of Japanese companies outside Japan can deliver many of the market participation benefits—revenue for future technology development and learning from demanding customers—that contribute to maintaining and enhancing technological capabilities. Since the production of Japanese auto companies outside Japan is likely to grow much more quickly than production inside Japan, this will represent a significant growth market during the coming decade.

Advanced Technology

Advanced technology is increasingly incorporated into automobiles. One U.S. program aimed at speeding the development of new technologies and their incorporation into automobiles is the Partnership for a New Generation of Vehicles (PNGV). PNGV is a partnership between a number of U.S. government agencies and the Big Three automakers. The goals are to improve competitiveness in manufacturing, implement commercially viable innovations from ongoing research in conventional vehicles, and develop vehicles that can achieve up to three times the fuel efficiency of comparable 1994 family sedans.[28]

Over the next several decades there is a good possibility that more fundamental technological shifts will occur in the auto industry. These include increasing utilization of electric and other alternatively powered vehicles to reduce emissions and increase energy efficiency and advances to facilitate higher traffic volumes and greater safety through the use of advanced vehicle navigation and control systems.

Electric vehicles are one area of significant R&D effort in the United States and Japan. Table 5-3 compares the U.S. and Japanese approaches toward electric vehicles. In contrast to U.S. efforts, which have focused on research and development and mandates to establish a market, approaches by Japan and several other countries have placed relatively more emphasis on public demonstration projects for government and utility fleets that establish public recharging and maintenance facilities.[29] The Japanese government also helps support the Japan Electric Vehicle Association (JEVA), which acts as an information clearinghouse and promoter.[30]

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[26] U.S. Department of Commerce, International Trade Administration, "Japan-U.S. Auto Parts Sales Trends," December 4, 1994.

[27] Ibid.

[28] Partnership for a New Generation of Vehicles, *Program Plan*, November 1995.

[29] U.S. Congress, General Accounting Office, *Electric Vehicles: Likely Consequences of U.S. and Other Nations' Programs and Policies* (Washington, D.C.: U.S. Government Printing Office, December 1994).

[30] See "JEVA Continues NEDO Contract to Promote Electric Vehicles," *EV Network*, August 28, 1995.

TABLE 5-3 Key Elements of Electric Vehicle Programs

	United States	Japan
Number of electric vehicles in operation, December 1994	1,000	1,600
Goal for Year 2000	70,600 (based on state requirements)	200,000 (national target)
Purchase programs and incentives	$4,000 federal tax credit for fleets; some state incentives; California-type mandates (six states)	50% national cost subsidy; various local subsidies; reduced purchase and possession tax; 7% business tax credit; subsidized leasing
Vehicle and infrastructure	small fleet demonstrations	Ecostation 2000; several national and local demonstrations
Vehicle and battery research	U.S. Advanced Battery Consortium	Lithium battery project

SOURCE: Adapted from U.S. Congress, General Accounting Office, *Electric Vehicles: Likely Consequences of U.S. and Other Nations' Programs and Policies* (Washington, D.C.: U.S. Government Printing Office, 1994).

Electric vehicles face significant technological and market barriers. Current electric vehicles utilizing lead acid batteries require difficult trade-offs in performance, range, and ease of recharging. Batteries are therefore the focus of electric vehicle R&D efforts. The United States and Japan appear to be the only countries with large-scale publicly-funded advanced battery programs. In the United States the Big Three automakers formed the U.S. Advanced Battery Consortium (USABC) in 1991, and later that year reached agreement with the U.S. Department of Energy (DOE) and the electric utility industry to cooperate in support of research and testing of advanced batteries.[31] The program has involved contracts with battery developers and cooperative research and development agreements with DOE labs to support a variety of approaches toward battery technology development and testing. As the name suggests, Japan's main battery research program, the Lithium Battery Electric Power Storage Research Association (LIBES), is also focused on lithium batteries.

There are several interesting differences between the U.S. and Japanese efforts. First, the USABC involves a significantly higher overall level of funding than LIBES, but the Japanese effort does not include development of intermediate technologies as USABC does. Second, in contrast to USABC, where participation by automakers is a central element of the program, auto

[31] U.S. Congress, General Accounting Office, *Electric Vehicles: Efforts to Complete Advanced Battery Development Will Require More Time and Funding* (Washington, D.C.: U.S. Government Printing Office, August 1995).

manufacturers are not direct participants in LIBES. Third, because the U.S. industrial base in rechargeable batteries is somewhat thin, several of the participating battery companies are non-U.S. firms, and most of the participating U.S. battery firms are either small or are not in the battery business, one exception being Duracell. No foreign-owned companies are participating in LIBES. Another interesting aspect of the Japanese program is that it does not include Sony, the current market leader in lithium ion batteries for portable electronics applications.

Japan currently leads the world in developing and mass producing rechargeable batteries.[32] Research on a rechargeable lithium ion battery was first reported in a scientific conference in Japan in 1985.[33] Although they have a number of advantages, and Japanese companies are already marketing small lithium ion batteries for use in a variety of portable electronic devices, making the technology feasible for use in electric vehicles is a difficult long-term proposition. Still, the Japanese government program encourages the makers of batteries to invest in long-term research. Even if lithium ion batteries are not widely used in future automobiles, this basic research could deliver benefits in consumer electronics and in other downstream sectors. Japanese battery makers also appear to be taking a global view toward marketing and partnerships. Although they have only been commercialized in the past few years, Japanese companies have already announced several joint ventures and other plans to produce lithium ion and other advanced batteries outside Japan.[34]

Intelligent vehicle and highway systems are also a focus of government and industry technology development efforts in the United States, Japan, and Europe. Efforts are driven by a common need to improve traffic flows and safety on increasingly crowded highways. Intelligent vehicle and highway systems are a huge potential market, not only in developed countries but in rapidly growing Asian economies where traffic congestion is already a major problem in large cities. Vehicles and systems will draw on a wide range of technologies, including sensors, electronics, radar, human interface, information systems, and image processing. The Japanese government has increased R&D in this area in recent years. Five ministries budgeted 62.5 billion yen for this effort in fiscal 1996 (over $500 million at current exchange rates), compared with U.S. government funding of $222.8 million.[35]

Outlook for 2007

• *While Japanese companies still hold a manufacturing and product development edge, the U.S. auto industry has made considerable progress in catching up. A more level playing field is emerging in the industry as access to the Japanese market improves and Japanese-owned manufacturing and R&D facilities in the United States make greater contributions to U.S. employment and living standards. Although the nationality of companies is becoming less of a differentiating factor in the auto industry, the U.S. economy still derives relatively greater benefit from the success of U.S.-based companies.*

• *Japanese and U.S. companies will likely remain in the forefront of the global auto industry. Current production trends are likely to continue for at least the next few years. Although appreciation of the dollar in 1995 and 1996 slowed progress, the U.S. auto trade deficit with Japan will likely continue to shrink somewhat.*

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[32] "Lithium-ion Cells in Mass Production," *Road Warrior News*, April 1995.

[33] Ko Shimada, "Lithium Ion Battery: A Key Device for the Multimedia Age," *Japan 21st*, October 1994.

[34] "NEC to Produce Batteries in Canada," *Nikkei Weekly*, August 1, 1994, p. 8.

[35] Asian Technology Information Program, "Intelligent Transport Systems: 1996 Japanese Budget/Strategy," ATIP Report, February 1996.

• Asia will be a major competitive battleground of the global auto industry. The ability to invest will depend on strengths built in core developed-country markets as much as effective Asia strategies per se. It is likely that firms from neither country will be able to dominate.

• The South Korean industry will be a major wild card over the next few years. South Korea is building significant capacity, and Korean companies could pose a challenge to U.S. and Japanese firms within the next decade. The European industry is likely to experience significant consolidation.

• Both U.S. and Japanese companies will be prominent in the emerging global supplier base, although second- and third-tier companies in each country will face significant challenges. U.S. suppliers will need to make further progress in implementing the Toyota Production System, and Japanese suppliers will need to follow their customers offshore and develop new international business. The ability of foreign-based companies, particularly suppliers, to participate in the Japanese market is still an issue.

ADVANCED MATERIALS

The field of advanced materials is comprised of a diverse group of technologies, including high-performance glass and ceramics, polymers, specialty metals, precision coatings, and composite materials. They are applied in a wide range of industries, including chemicals, electronics, aerospace, and automobiles. A comprehensive evaluation of U.S.-Japan capabilities and cooperation is beyond the scope of this study. Fortunately, a number of evaluations of specific areas of advanced materials research and application have been done in recent years by the Japan Technology Evaluation Center.[36] This section will review several general features of technology development and commercialization activities in the two countries and the implications for the future.

General U.S.-Japan Differences

The United States and Japan both possess strong capabilities in advanced materials R&D and commercialization. U.S.-based companies tend to be strong in such areas as gas membranes, polymers and polymer composites (although Japanese firms are strong in carbon fiber), specialty metals (particularly for aerospace applications), and utilization of modeling and simulation in the development of materials. Japanese firms are strong in coatings (as are German companies),

[36] Relevant studies include Lawrence Tannas, Jr., William E. Glenn, Thomas Credelle, J. William Doane, Arthur H. Firester, and Malcolm Thompson, *JTEC Panel Report on Display Technologies in Japan* (Baltimore: Loyola College in Maryland, 1992); Dick J. Wilkins, Moto Ashizawa, Jon B. DeVault, Dee R. Gill, Vistap M. Karbhari, and Joseph S. McDermott, *JTEC Panel Report on Advanced Manufacturing Technology for Polymer Composite Structures in Japan* (Baltimore: Loyola College in Maryland, 1994); Michael J. Kelly, William R. Boulton, John A. Kukowski, Eugene S. Meieran, Michael Pecht, John W. Peeples, and Rao R. Tummala, *JTEC Panel Report on Electronic Manufacturing and Packaging in Japan* (Baltimore: Loyola College in Maryland, 1995); C. Judson King, Edward L. Cussler, William Eykamp, George E. Keller II, H.S. Muralidhara, and Milton E. Wadsworth, *JTEC Panel Report on Separation Technology in Japan* (Baltimore: Loyola College in Maryland, 1993); M.S. Dresselhaus, R.C. Dynes, W.J. Gallagher, P.M. Horn, J.K. Hulm, M.B. Maple, R.K. Quinn, and R.W. Ralston, *JTEC Panel Report on High Temperature Superconductivity in Japan* (Baltimore: Loyola College in Maryland, 1989); and Stephen R. Forrest, Larry A. Coldren, Sadik C. Esener, Donald B. Keck, Frederick J. Leonberger, Gary R. Saxonhouse, and Paul W. Shumate, *JTEC Panel Report on Optoelectronics in Japan and the United States* (Baltimore: Loyola College in Maryland, 1996).

ceramics and ceramic composites, and primary metals. U.S. and Japanese companies are nearly equivalent in liquid membranes, optoelectronic materials, and superconducting materials.[37]

Relative U.S. and Japanese strengths have been shaped by factors in their respective business environments. For example, the strength of Japanese companies in electronics and the large potential market for blue lasers and light-emitting diodes in optical data storage and other areas has spurred Japanese companies to invest significant amounts in R&D to develop the enabling materials.[38] U.S. strength in aerospace and large defense-related government investments in aerospace materials development underlie U.S. leadership in this area.

Japanese companies also have tended to be strong in materials fields that require a long-term investment focus, call for persistent efforts to lower costs and improve quality in manufacturing, and are not highly profitable. Long-term investment focus in relatively low-profit fields has been aided by the willingness of firms to accept lower profits, *keiretsu* and other close links between companies that lower market risks, and in some cases the preference of Japanese industrial customers for Japanese-made products, even when they cost more. U.S. companies, with very different incentives, are not able to operate in the same way. The business environment in Japan is changing to some extent, particularly in consumer-driven markets. There is less willingness to settle for low profits and buy Japanese products even where comparable products cost less. However, powerful interests still favor the status quo.

Concentrated Supply and Dependence

One very important application of advanced materials is ceramic semiconductor packages. The global market for these products is dominated by Japanese companies, with Kyocera being the largest. Only a few U.S.-owned suppliers remain. Coors Electronic Package Company, a division of ACX Technologies, sells products on the open market. IBM also is strong in this area but has traditionally been a captive supplier.

Several years ago the Department of Commerce conducted an investigation of the national security implications of U.S. dependence on Japan for ceramic packages.[39] Ceramic packages are critical components in military systems. Ultimately, the U.S. government decided not to limit Japanese imports or directly subsidize increased U.S. production of ceramic packages but did launch an R&D program to strengthen the U.S. technology base. One of the possible economic risks for the United States of dependence on Japanese or other foreign sources of critical components, materials, and manufacturing equipment lies in the possibility that suppliers may delay or deny access to the most advance products to U.S. customers. This would give Japanese customers a competitive edge through preferred access.[40] Although Japanese companies still control large global market shares in some critical supplier areas, particularly electronic materials, concern over this issue has declined somewhat in recent years as the Japanese industry's momentum in global electronics has slowed and competition has reappeared in some areas where Japanese companies had established dominance.

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[37] David Duke, presentation to the Competitiveness Task Force, January 1995.

[38] Asian Technology Information Program, "Blue LEDs: Breakthroughs and Implications," August 1995. It was a relatively small, privately held company, Nichia Chemical, that developed the first commercially available bright blue LED.

[39] U.S. Department of Commerce, Office of Industrial Resource Administration, *The Effect of Imports of Ceramic Semiconductor Packages on the National Security: An Investigation Conducted Under Section 232 of the Trade Expansion Act of 1962* (Springfield, Va.: National Technical Information Service, 1993).

[40] U.S. Congress, General Accounting Office, *U.S. Business Access to Certain Foreign State-of-the-Art Technology* (Washington, D.C.: U.S. Government Printing Office, 1991).

Another possible long-term risk arises from the potential for a given technology to become more important over time. If the United States does not possess capabilities in such an area, the U.S. economy may be at a disadvantage in developing next-generation products. Some experts believe, for example, that ceramic packages will increasingly shift from a passive role to a more active and critical role in electronics systems.[41] In this context some experts believe that government investments to encourage vertical partnerships between U.S. ceramic users and suppliers can help maintain U.S. capabilities and ensure that U.S. companies are able to pursue technological and product opportunities made possible by more advanced packages.

Market Participation and Technological Capabilities

Just as suppliers of advanced materials can provide a competitive edge to their customers, makers of advanced materials benefit from close interaction with demanding users. Box 5-1 describes an important example and illustrates that the ability to participate in the Japanese market is a major determinant of whether the United States will derive maximum economic benefits from science and technology interaction with Japan. An expanded discussion of this point is included in Chapter 6.

Outlook for 2007

Because the advanced materials field is composed of such a wide variety of industries and technologies, it is difficult to characterize the outlook for the field in a general way. Since advanced materials are intermediate goods sold to businesses, shifts in markets and competition will be heavily influenced by general changes in business practice and culture in Japan. Key issues include whether the Japanese business climate will continue to allow companies to maintain long-term R&D investment in areas that are only marginally profitable, whether a new market in advanced materials emerges of a scale comparable to current demand for electronic ceramics or glass for fiber optic cables, and whether new competitors emerge from other countries.

BIOTECHNOLOGY AND HEALTH CARE

Broadly defined, biotechnology includes "any technique that uses living organisms (or parts of organisms) to make or modify products, to improve plants or animals, or to develop microorganisms for specific use."[42] Today, biotechnology is applied in health care, agriculture, the environment, and other areas. Health care is a very broad industry category that includes pharmaceuticals, medical equipment and supplies, hospital management, and medical information management. The focus of this section is mainly on biotechnology, with some contextual discussion of health care markets and products outside biotechnology. As is the case with the information industries, the difficulty in formulating a neat definition illustrates the fast-moving character of research and innovation in this field.

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[41] William M. Flock, presentation to the Competitiveness Task Force, January 1995.

[42] U.S. Congress, Office of Technology Assessment, *Biotechnology in a Global Economy* (Washington, D.C.: U.S. Government Printing Office, 1991), p. 19.

Background

Since Genentech was founded in 1976, there has been an explosion in research and commercialization in biotechnology, and the United States has been at the center of this activity. U.S. biotechnology companies number over 1,300, with nearly $13 billion in annual revenue and

Box 5-1 The Link Between Participation in the Japanese Market and U.S. Technological Capabilities: Glass for Flat Panel Displays

Corning Inc., is the leading supplier of substrate glass for the production of active matrix liquid crystal displays (AMLCDs), the largest and most rapidly growing segment of the flat panel display market. AMLCDs are widely utilized in laptop computers and a range of more specialized applications, including avionics. Japanese companies have pioneered the commercialization of AMLCDs and currently dominate the AMLCD market, holding a 98 percent share in 1994. For Corning, establishing and maintaining a strong position in the glass substrate market, estimated to be about $250 million in 1996, has therefore depended on participation in the Japanese market. In light of the rapid advances in product and process technology that have characterized AMLCDs in recent years, close contact with customers and the incorporation of customer feedback into technology and product development efforts have been critical for Corning and will likely remain so.

An example drawn from Corning's participation in the AMLCD glass substrate market illustrates the importance of market participation for maintaining the technological capabilities underlying competitiveness. This example shows how staying ahead in a technology often depends on seeking out and utilizing feedback from demanding customers. Manufacturing glass substrates for AMLCDs involves continuous improvement in achieving uniform thickness, eliminating particles, and minimizing warp. By the early 1990s, it had become clear to Corning that its existing glass composition had several drawbacks that would need to be addressed in order to meet the future anticipated needs of display makers. It was also clear that a number of competitors had launched aggressive development programs for next-generation AMLCD substrate glass.

Developing the improved glass composition involved, at the outset, an effort to specify the technical requirements of users and the necessary physical characteristics of the glass. Corning devised a demanding set of requirements for the new glass and toured R&D labs of display makers in the United States, Europe, and Japan to determine whether these specifications would meet the anticipated needs of customers. All of the companies visited except for one agreed that the specifications would meet their future needs. This customer, one of the largest Japanese display makers, recommended that Corning change one of the specifications.

Corning reexamined its assumptions and decided to develop its glass with the specification suggested by this Japanese customer. Now that the improved Corning substrate and other glasses are coming onto the market, it is clear that the Japanese customer was right. The performance enabled by the change distinguishes Corning's glass from competing products.

SOURCE: Communication with Corning Inc., January 1996.

over 100,000 employees.[43] The U.S. pharmaceutical industry constitutes an even larger force, with shipments exceeding $60 billion per year.[44] Japan has a significant pharmaceutical industry, but it has traditionally trailed the United States and Europe in sales and innovation.[45]

Several factors contribute to U.S. strength in biotechnology and health-care-related fields. Perhaps most important is the strong federal government support for fundamental research in biomedical fields over many years through the National Institutes of Health and other agencies. Scientific discoveries in biotechnology are more closely linked to product development than is the case in other fields, such as electronics.[46] A second factor contributing to U.S. strength in biotechnology is a well-developed private equity market and institutions to support investment in commercializing technology through the creation of new firms. Business culture plays a role as well. In contrast to Japan or Western Europe, a U.S. entrepreneur whose high-risk commercial venture fails does not necessarily compromise her or his future career. To the contrary, such a failure may be seen as "paying one's dues." The United States also has a large and growing market for health care products and is relatively open to improved treatments and new technologies.

As the first U.S. "biotech boom" unfolded in the early 1980s, Japanese policymakers and industry were quick to see the area as one with significant future potential, and organized several government-industry initiatives to improve Japanese capabilities. At the same time, Japanese companies, both traditional pharmaceutical ones and nontraditional players from food, cosmetics, heavy equipment, and other sectors, formed a large number of linkages with emerging U.S. biotechnology companies to gain access to their technology.[47] Japanese companies also formed links with U.S. research universities and institutes and established a number of R&D facilities in the United States.[48] Japanese companies were not alone in these efforts. In recent years large European pharmaceutical companies have made significant direct investments in U.S. pharmaceutical and biotechnology companies. In 1993, 26 percent of R&D spending by foreign-affiliated companies in the United States was in pharmaceuticals, and 38 percent of all U.S. industry R&D expenditures in pharmaceuticals were made by foreign affiliates.[49]

The early and mid-1990s witnessed something of an "internationalization pause" for Japanese companies.[50] Several factors were responsible, including Japanese industry restructuring and retrenching during the postbubble recession, the fact that only a few of the many links with U.S. companies and universities had resulted in significant payoffs, and a trend toward cheaper and less-risky deals as Japanese partners moved down the learning curve of collaborating with small U.S. companies developing unproven technologies. The U.S. biotechnology industry itself has experienced its own ups and downs, and expectations have

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[43] Biotechnology Industry Organization (BIO), *The Editors' and Reporters' Guide to Biotechnology, 2nd Edition* (Washington, D.C.: BIO, 1996).

[44] Council on Competitiveness, *Endless Frontier, Limited Resources* (Washington, D.C.: Council on Competitiveness, 1996).

[45] "Gyo ho no kenkyu" (Study of the Industry Law), *Nihon Keizai Shimbun*, July 31, 1995, p. 5.

[46] Although a complete explanation of why this is the case would require a significant amount of space, perhaps the most important reasons are the newness of biotechnology and the fact that most pharmaceutical products are research-based single-bullet products, lacking the general requirement that exists in electronics for new products to mobilize and interface with a significant existing infrastructure.

[47] For the period 1981-1991, the database of the North Carolina Biotechnology Center, Institute of Biotechnology Information, contained 231 cases. National Research Council, *U.S.-Japan Technology Linkages in Biotechnology: Challenges for the 1990s* (Washington, D.C.: National Academy Press, 1992).

[48] Ibid.

[49] Donald H. Dalton and Manuel G. Serapio, Jr., *Globalizing Industrial Research and Development* (Washington, D.C.: U.S. Department of Commerce, 1995).

[50] Presentation by Carole Cooper Martin to the Competitiveness Task Force, January 1995.

tended to oscillate wildly as particular biotechnology products become successful or produce disappointing results in clinical trials.

Today, the United States still enjoys broad leadership in biotechnology research and commercialization. Using a -1 to +1 scale, with zero being parity, a recent Japanese government report ranks Japan's level of basic research in life sciences as -0.9 compared with the United States and -0.5 compared with Europe.[51] However, there are several U.S.-Japan issues and trends in areas such as investments in R&D capabilities and market participation that will have an impact on U.S. capability to derive maximum benefit from research and U.S.-Japan links in the future.

Current Issues

Research and Commercialization Capabilities

Although not conducting biomedical research on nearly the scale that the United States does, Japan is persisting in its efforts to improve its fundamental research base and is increasing support for targeted and innovative programs. One example with a significant track record is the Science and Technology Agency's Exploratory Research for Advanced Technology (ERATO) program, which has been in operation since the early 1980s. In a departure from traditional Japanese funding patterns in which small grants are funneled to senior researchers, ERATO provides five-year nonrenewable funding for high-risk, cross-disciplinary research by diverse teams primarily composed of younger researchers.[52] Life sciences projects have become more prominent among ERATO efforts over the years. A recent U.S. evaluation of ERATO found that the project has supported a significant amount of high-quality research and has had an important and positive impact on Japan's research culture.[53] Since 1995, the main Japanese research funding agencies have all launched large new programs to support basic research, and each of these has a significant biotechnology or life sciences emphasis.[54]

In addition to increased funding for innovative programs in Japan, international links, particularly to the United States, are still an important element in the strategies of Japanese companies and government agencies to improve capabilities in biotechnology. Although these linkages have not yet turned Japan into a commercial biotechnology powerhouse, a large number of Japanese life scientists have gained experience as visiting researchers at the National Institutes of Health.[55] Japanese companies are continuing efforts to work with U.S. universities and U.S.

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[51] See Sangyo Kozo Shingikai Sogo Bukai Sangyo Gijutsu Shoiinkai (Industrial Structure Advisory Committee, Industrial Technology Subcommittee) and Sangyo Gijutsu Shingikai Sogo Bukai Kikaku Iinkai (Industrial Technology Advisory Committee, Planning Subcommittee), *Kagaku Gijutsu Sozo Rikkoku e no Michi o Kirihiraku Shiteki Shisan no Sozo, Katsuyo ni Mukete* (Clearing a Path Toward a Nation Based on Creative Science and Technology; Toward Creating and Utilizing Intellectual Assets), Executive Summary, June 1995.

[52] Japanese Technology Evaluation Center, *Japan's ERATO and PRESTO Basic Research Programs* (Loyola, Md.: JTEC, 1996).

[53] Ibid.

[54] These programs include Core Research for Evolutionary Science and Technology of the Science and Technology Agency (life phenomena is one of four major disciplinary categories); the Research for the Future program of the Ministry of Education, Science, and Culture (life sciences is one of the three broad categories); and the Innovative Industrial Technology R&D Promotion Program of the Ministry of International Trade and Industry (27 of 109 projects approved in the first year were in biotechnology). Total funding for these programs was about $260 million for fiscal year 1996. See National Science Foundation Tokyo Office, *Report Memoranda 96-14, 96-15, and 96-16* (Tokyo: National Science Foundation, 1996).

[55] There are usually 2500 or more foreign researchers at NIH at any given time, the majority supported by NIH through the NIH Visiting Program for stays of longer than three months. As of March 1997, the top three sending

biotechnology companies. In the long run, the commercialization mindset and familiarity with high-performance research and product development practices is serving to upgrade skills in Japan.[56]

Biotechnology has been a focus of concerns about asymmetrical participation in government supported R&D. The large number of Japanese and other foreign researchers at NIH contrasts with the small number of U.S. life science researchers in Japan. Assessing the cost and benefits, and developing approaches to bring about greater symmetry, are not straightforward exercises. For example, a scarcity of good opportunities for post doctoral fellowships in Japan lies behind the asymmetry, encouraging Japanese researchers to do their "post-docs" overseas, and discouraging foreign researchers from traveling to Japan. The training and experience that these researchers gain is undoubtedly a benefit for Japan.[57] The United States benefits as well, since Japanese and other foreign researchers serve as a high quality, relatively low cost human resource, helping NIH to undertake its research missions more efficiently. The committee believes that the best way to redress this asymmetry is for Japan to continue efforts to improve its own research base and expand opportunities for "post-docs," and for the United States to continue to support programs that send U.S. researchers to Japan.

Japanese government support for life sciences and biotechnology research also has contributed to U.S. capabilities. The Human Frontier Science Program was established in 1989 with Japanese initiative and funding to support international collaboration in multidisciplinary brain research and molecular biology (see Box 2-2). The program provides support for about 20 U.S. research teams and 10 research fellows each year and may serve as a positive example of Japanese international scientific leadership. The ERATO programs also frequently involve U.S. researchers, and the Japanese government has increased support for a range of international research exchanges.

As for corporate links, one of the most successful has been the alliance between Amgen and Kirin Brewery.[58] Kirin's participation in a joint venture with Amgen was critical in the effort to commercialize Amgen's first two blockbuster products, Epogen and Neupogen. More recently, Kirin is reported to have made important technological contributions in the development of thrombopoietin, a blood platelet formation factor.[59]

Market Asymmetries: Regulation and Intellectual Property

U.S.-Japan competitiveness and cooperation in life sciences and biotechnology are also affected by market factors. Under the post-World War II Japanese policies of limiting imports and inward direct investment, the Japanese pharmaceutical industry was able to grow mainly by licensing foreign products and developing "me too" compounds. Under Japan's system the Ministry of Health and Welfare is responsible for drug approval and also sets the reimbursement schedule for drugs and medical procedures under Japan's national health insurance system. Since reimbursement levels for drugs have traditionally been more generous than those for medical

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countries were Japan (329), China (226), and Italy (144). In 1996, the Japan Society for the Promotion of Science launched a program to provide support for up to 60 Japanese post doctoral fellows at NIH. As of May 1997, 18 Japanese post-docs were participating in the program. Communication from NIH, May 1997.

[56] Carole Cooper Martin, presentation to Competitiveness Task Force, January 1995.

[57] Anecdotal evidence and past surveys by NIH indicate that very few of the Japanese visitors are affiliated with industry either before or after their stay. See Committee on Japan, *Foreign Company Access to U.S. National Laboratories: Report of a Workshop,* August 1994.

[58] National Research Council, *U.S.-Japan Technology Linkages in Biotechnology*, op. cit.

[59] "Amgen, Partner Kirin Acquire Rights to Danish Firm's Blood-Clotting Protein," *The Wall Street Journal*, August 16, 1995, p. B2.

procedures and Japanese doctors rather than pharmacists dispense most drugs in Japan, there are strong incentives for doctors to prescribe medication.

In recent years the environment for foreign direct investment in Japan has improved, and the pricing system for drugs has been changed to reward more innovative treatments, with the reimbursement price declining every year after a drug is introduced.[60] Since Japan is an affluent society whose population is aging rapidly, it is a very attractive pharmaceutical market. Large U.S. and European pharmaceutical companies have been active in recent years in acquiring Japanese companies, acquiring full ownership of marketing joint ventures with Japanese firms, and establishing R&D labs and other business infrastructure.[61] In addition, the trend toward mergers between U.S. and European pharmaceutical companies has led to consolidation and streamlining of operations in Japan.

While larger U.S. and European companies are better able to access the Japanese market today than in the past, it is still difficult for smaller U.S. biotechnology firms. One issue is Japan's drug approval system. Although on average the system does not appear to be more onerous or difficult to deal with than the U.S. system, the unification of industry promotion and regulatory power within the Ministry of Health and Welfare has sometimes resulted in manipulation of the process to favor domestic corporate interests. One example is the Japanese government's delay in stopping the distribution of HIV-tainted blood in the early 1980s because screening and treatment of the products would have imposed higher costs on industry. About 2,000 people were infected and about 400 have died so far because of this negligence, which was only recently exposed.[62] Conflicts of interest and lack of expertise are problems in the Japanese drug approval system, which sometimes leads to the approval of domestic drugs before risks are adequately understood or delays in approval of non-Japanese drugs whose benefits are evident.[63] Although larger foreign pharmaceutical companies have the resources to overcome these obstacles, smaller U.S. biotechnology companies often find it difficult to establish an independent marketing presence in Japan.

Intellectual property protection is another key market access issue that is particularly important to biotechnology companies. Several features of the Japanese patent system, including the approval process and judicial enforcement, have posed difficulties for U.S. companies in the past. These include a pregrant opposition system that allows competitors to hold up or narrow the scope of a patent, lack of foreign language filing, and the general narrower scope of Japanese patents compared with U.S. patents.[64] Due to the lengthy product development and approval process for pharmaceutical products, emerging U.S. biotechnology companies have to make substantial investments before realizing a revenue stream from their products, and a strong patent position is a key asset in gaining investment backing. When intellectual property protection in

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[60] Some credit a 1986 Market-Oriented, Sector Selective (MOSS) agreement on pharmaceuticals between the United States and Japan as having a positive impact on the ability of foreign companies to gain approval for new drugs. See American Chamber of Commerce in Japan, *Making Trade Talks Work: Lessons From Recent History* (Tokyo: ACCJ, 1997).

[61] Aki Yoshikawa, presentation to Competitiveness Task Force, January 1995.

[62] Kevin Sullivan, "Health Minister a Tonic to Apathy? Japanese is Battling Bureaucracy and Winning People's Support," *The Washington Post*, July 10, 1996, p. A12.

[63] Masonori Fukushima, "Clinical Trials in Japan," *Nature Medicine*, January 1995. Interestingly, Fukushima advocates foreign pressure to bring about changes in the Japanese system. He does not mention the possibility of the Japanese public, whose health is being compromised because of shortcomings in the system, providing the impetus for change.

[64] U.S. Congress, General Accounting Office, *U.S. Companies' Patent Experiences in Japan* (Washington, D.C.: U.S. Government Printing Office, 1993), and National Research Council, *Corporate Approaches to Protecting Intellectual Property* (Washington, D.C.: National Academy Press, 1994).

Japan is problematic, the U.S. firm is in a weak position to participate in the Japanese market directly and feels pressure to license its product to a Japanese partner. Meanwhile, Japanese pharmaceutical companies have been active in patenting human genes in the United States.[65]

In 1994 the U.S. and Japanese governments signed two agreements to address intellectual property issues.[66] Under the agreements, pregrant opposition by third parties would be ended, foreign language filing would be allowed, an accelerated examination system would be instituted, and the practice of awarding dependent compulsory licenses would be ended under the Japanese system. The United States was obligated to change its patent term from 17 to 20 years and to begin publication of pending applications 18 months after filing. In light of the importance of entrepreneurial companies in commercializing new technologies in the United States, and the critical role of intellectual property protection in determining whether U.S. innovators will be able to participate in the Japanese market on favorable terms, it will be important for the United States to monitor implementation of the agreements, and to continue efforts to improve intellectual property protection in rapidly growing markets.

Outlook for 2007

- *Japan's R&D strength in life sciences and biotechnology is likely to rise considerably. If the U.S. government and U.S. industry continue to invest in U.S. R&D and capability to access developments in Japan, it is possible that cooperation can build on positive examples, such as the Human Frontier Science Program, and deliver significant mutual benefits.*
- *In pharmaceutical and biotechnology products, large foreign firms are likely to improve their position in Japan. Japanese firms will continue to be pressed. However, unless regulatory and intellectual property-related market barriers to small U.S. biotechnology companies are addressed, Japanese companies will continue to enjoy significant bargaining power vis-à-vis small U.S. biotechnology companies.*

SEMICONDUCTOR MANUFACTURING EQUIPMENT

Closely linked to the rapid competitive advances made by the Japanese semiconductor device industry during the late 1970s and 1980s were parallel gains by Japanese firms in the semiconductor manufacturing equipment (SME) and materials sectors. Corresponding rapid market reversals suffered by U.S. equipment makers raised the possibility that there would be no competitive U.S.-based presence in some critical areas of the microelectronics supplier infrastructure. Some observers raised serious national security and economic concerns.[67] Dependence on Japan for categories of semiconductor equipment could lead to aggravated problems for U.S. device makers if Japanese equipment companies denied or delayed access to advanced products already available to Japanese chipmakers.[68]

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[65] "Japanese drug and chemical companies held nearly half of the 900 privately held DNA patents granted in the U.S., Europe and Japan between 1981 and 1995." See "Japan is Leading Race to Patent Genes of Humans," *The Wall Street Journal*, April 4, 1996, p. B6.

[66] U.S. Trade Representative, *1994 Annual Report* (Washington, D.C.: U.S. Government Printing Office, 1995).

[67] For example, National Advisory Committee on Semiconductors, *A Strategic Industry at Risk*, November 1989.

[68] In a 1991 study 22 of 59 U.S. companies contacted reported difficulties in obtaining advanced products from Japanese suppliers. Semiconductor equipment was one of the most frequently mentioned problem areas. See U.S. Congress, General Accounting Office, *U.S. Business Access to Certain Foreign State-of-the-Art Technology* (Washington, D.C.: U.S. Government Printing Office, 1991).

Beginning in the second half of the 1980s, the United States took several policy steps aimed at slowing or halting the decline in semiconductors and related areas. The 1986 Semiconductor Trade Agreement with Japan aimed to stop the dumping that occurred during the market slump of the mid-1980s and improve access to the Japanese market. In 1987 a group of U.S. semiconductor companies and the U.S. Department of Defense formed the SEMATECH R&D consortium.[69]

Because of the SME sector's role as a key supplier industry for electronics more broadly, trends in this sector will continue to be watched closely. It is particularly appropriate to assess U.S.-Japan competitiveness in SME for this study because the industry has been a focus of U.S. competitiveness policy debate and serves to illustrate many of the generic strengths and weaknesses of the industrial and technology development structures of the two countries. An examination of recent trends and possible future developments here could shed light on the sustainability of recent U.S. competitiveness gains and the effectiveness of policy and industry approaches that have been taken in recent years.

Industry Evolution

The development and competitive dynamics of the SME industry are tightly linked to conditions in its customer base, the semiconductor device industry. In the early days of the semiconductor industry—the late 1950s and early 1960s—device makers such as Texas Instruments grew their own materials and designed and built their own tools.[70] This early period witnessed the growth of several specialized manufacturing equipment and materials companies such as Materials Research (sputtering equipment), Geophysics Corporation of America (step-and-repeat camera), and Thermco (diffusion oven).

However, it was only in the late 1960s and early 1970s that the SME industry truly emerged. Higher levels of device integration and performance, along with more stringent and sophisticated manufacturing demands, raised equipment development costs. At the same time, abundant technological opportunities and the availability of capital to fund ventures encouraged a stream of managers from existing device makers to form new firms. As capabilities grew in these dedicated equipment vendors, even large device makers increasingly turned to them for new process technology advances. Expanding business opportunities attracted market entry by existing manufacturers of other types of precision instruments, such as Varian Associates.

The environment in which the semiconductor and SME industries developed in the United States encouraged a "commoditization" of capabilities and arms-length market transactions.[71] Device makers would often modify equipment to improve performance, but these improvements were regarded as proprietary secrets and not shared with equipment makers. This discouraged long-term cooperative relationships and advance planning. By the mid-1970s, when a serious business slump hit the semiconductor market, the SME industry consisted of a few larger companies operating in several equipment segments (Varian, Perkin-Elmer, General Signal) and numerous small and financially vulnerable firms. The SME industry experienced a serious shakeout due to the slump, as chipmakers canceled equipment orders. When orders picked up again in the late 1970s, many equipment makers were wary of increasing production too quickly. Tight demand created crucial market opportunities for Japan's emerging SME companies.

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[69] U.S. Congress, General Accounting Office, *SEMATECH's Efforts to Strengthen the U.S. Semiconductor Industry* (Washington, D.C.: U.S. Government Printing Office, 1990).

[70] This historical overview borrows heavily from Jay Stowsky, *The Weakest Link: Semiconductor Production Equipment, Linkages and the Limits to International Trade,* BRIE Working Paper #27 (Berkeley, Calif.: August 1987).

[71] Ibid.

Until the late 1970s, the U.S. SME industry experienced considerable success in penetrating the Japanese market, enjoying an 80 percent share in 1975. U.S. equipment makers often utilized trading companies to distribute their equipment and provide the extensive servicing infrastructure necessary. Tokyo Electron Limited (TEL), today the largest Japanese SME company, started as a specialized distributor of foreign-made equipment, gaining considerable marketing and technological expertise. Through links with U.S. companies in several product categories, TEL was able to move from a distribution role to licensed Japanese production of U.S. designs to the introduction of its own competitive products. Although TEL is not closely linked through financial ties to any of its major Japanese customers, other Japanese equipment makers started as subsidiaries or closely affiliated suppliers of the major Japanese semiconductor companies.

Despite rapid gains in consumer electronics through the 1960s, in the early 1970s Japan's electronics industry appeared to be falling behind the rapid pace of innovation set by the United States in key areas such as computers and advanced integrated circuits. The coordinated industry-government strategy that was formulated at that time is today seen as one of the great success stories of Japan's industrial policy.

The VLSI (Very Large Scale Integration) project involved cooperation between MITI and Nippon Telephone and Telegraph, and focused on the development of capabilities needed to produce next-generation devices, particularly the necessary manufacturing equipment. R&D costs were split with industry, and activities included reverse engineering and incremental improvement of U.S. machinery.[72] Through this process, Japanese SME vendors forged close ties with device makers and developed a range of competitive products.[73]

Japanese device makers used a conservative approach to product and process design in order to beat U.S. firms in the introduction of the 64K DRAM (dynamic random access memory) in the late 1970s. With success in the rapidly growing DRAM market, Japanese device makers expanded capacity and purchases of domestic machinery, while U.S. merchant semiconductor companies were hard pressed to invest in new equipment.

These trends set the stage for dramatic shifts in market share. By the mid-1980s, Japanese SME vendors were well positioned to expand their share in the U.S. market, particularly in lithography, advanced testers, and other product categories most critical to the manufacture of advanced memories. Between 1980 and 1988, the share of the world SME market held by Japanese companies rose from 18 to 39 percent, while the share held by U.S. companies fell from 75 to 49 percent.[74] Just as Japanese gains in semiconductor devices were focused in DRAMs, a high-volume product known to drive advances in manufacturing processes, the competitive progress of Japanese SME firms was especially prominent in a few key product categories.

The foremost of these was lithography equipment used to transfer circuit patterns to silicon wafers.[75] Lithography is the step in the wafer process that determines the integrated circuit's (IC) feature size and is therefore a limiting step to increased IC capacity. As a result, lithography is

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[72] Ibid.

[73] Ibid. Stowsky mentions direct and indirect contributions of the VLSI program to the development of Nikon's wafer steppers; Canon's projection aligners; E-beam lithography equipment developed by Hitachi, Toshiba and JEOL; Advantest's testers; Ulvac's ion implantation system; Nikon's first X-ray aligners; Dai Nippon Printing's X-ray masks; Kokusai Electric's deposition-and-etch systems and ion implanters; Tokuda's dry etch machinery; and Ando Electric's testers.

[74] VLSI Research data appearing in U.S. Department of Commerce, Office of Industrial Resources Administration, *National Security Assessment of the U.S. Semiconductor Wafer Processing Equipment Industry*, 1991.

[75] Semiconductor manufacturing equipment can be divided into the machines used in the "front-end" processes of wafer fabrication and those used in the "back-end" assembly and testing stages. In the former category are lithography, deposition (including chemical vapor deposition or CVD), etch and strip, ion implantation, and thermal processing. Ibid., pp. 7-11.

widely considered to be the most important segment of the SME market. In optical wafer steppers, the largest lithography product category, the share of the world market held by U.S. manufacturers fell from 60 to 15 percent between 1984 and 1989, with Japanese share rising from 39 to 75 percent over the same period.[76]

By the late 1980s and early 1990s, Japanese SME firms were extending and consolidating their gains in the U.S. market through over 40 acquisitions of U.S. SME vendors.[77] The deterioration of this key segment of the U.S. electronics supply base raised concerns among U.S. companies in downstream industries and government. During this period, IBM and other U.S. companies took steps to ensure that Perkin-Elmer's lithography division would remain U.S. owned.[78] The sale of Semi-Gas Systems, a maker of gas-handling systems, to competitor Nippon Sanso was vocally opposed by some members of Congress and by the Bush administration on antitrust grounds.[79]

Market Trends and Market Access

As in other high-technology and manufacturing industries in which Japanese companies made rapid gains in the 1970s and 1980s, the situation in the SME industry has shifted considerably in recent years. The share of the world SME market held by U.S. vendors has recovered somewhat and stood at 53 percent in 1994, while the Japanese share stood at 42 percent of the roughly $17 billion global market.[80] Although Japanese companies continue to dominate key areas such as lithography, even here a modest U.S. resurgence has been occurring. Several factors have contributed to halting the decline of the U.S. SME industry's competitive position in recent years.

The most obvious has been a shift in market trends. A consistent trend in semiconductor manufacturing has been the increase in minimum efficient scale. The cost of producing a square centimeter of silicon has gone down, but the entry cost for a new fabrication facility, or "fab," has gone up to an average of $1 billion. However, the payback on a billion-dollar fab now occurs in as little as three to five years. At the same time, the cost presented by equipment has risen from 40 to 70 percent of the total, partly due to the need to assure redundancy if equipment should break down.

Just as the earlier problems suffered by U.S. device makers contributed to the difficulties of domestic SME vendors, the improving position of the U.S. semiconductor industry over the past few years has helped fuel a U.S. SME rebound. In response to Japan's push in DRAMs, most U.S. merchant firms chose to exit the memory business and focus on higher-margin, more design-intensive logic devices. These segments of the market have grown considerably in recent years, particularly the microprocessor market, which is dominated by Intel. Consequently, capital

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[76] Ibid.

[77] National Research Council, *U.S.-Japan Strategic Alliances in the Semiconductor Industry: Technology Transfer, Competition, and Public Policy* (Washington, D.C.: National Academy Press, 1992), p. 115.

[78] Perkin-Elmer's lithography assets were eventually split up. The E-beam business was spun off into a separate company, Etec, owned by a coalition of companies, including IBM. A controlling interest in the optical lithography operation was bought by Silicon Valley Group.

[79] The inter-agency Committee on Foreign Investment in the United States (CFIUS) ruled that the sale did not pose problems for U.S. national security. The Department of Justice then challenged the sale on antitrust grounds but the challenge was turned down in court. Laura D'Andrea Tyson, *Who's Bashing Whom: Trade Conflict in High Technology Industries* (Washington, D.C.: Institute for International Economics, 1992), pp. 146-147.

[80] VLSI Research data.

equipment spending by U.S. chipmakers has followed an upward trend.[81] Meanwhile, the 1993-1994 economic slump in Japan suppressed growth in the semiconductor market, while the share of foreign semiconductor makers in Japan has improved.

Perhaps the most important end-market development has been the breaking of Japan's dominance of the DRAM market by the entry of Samsung and other Korean conglomerates.[82] The Korean market has been the most rapidly growing regional semiconductor equipment market in recent years, and U.S. SME vendors have enjoyed a higher market share in Korea than in Japan.

Although the rapid improvement in business climate enjoyed by U.S. SME vendors in the 1993-1995 period has leveled off, and some parts of the chip industry have suffered serious slumps, U.S. SME vendors should continue to enjoy relatively favorable market trends in the next few years. Particularly interesting is the trend toward increased investments by Japanese chipmakers in capacity outside Japan, including several facilities being built in partnership with U.S. companies. Some U.S. industry experts have expressed continuing concern about access to the Japanese market on the part of U.S. SME vendors. Since Japan is a major component of the overall market, participation there is necessary to gain a return on investment in new technologies. Box 5-2 develops a metric for associating market share and the ability to invest in technology development. A key question is whether Japanese-owned fabrication facilities outside Japan will bring increased opportunities for U.S. SME vendors with competitive equipment or whether Japanese chipmakers will find it desirable to maintain a high level of reliance on Japanese equipment vendors in their overseas facilities.[83]

One interesting example is Kulicke & Soffa (K&S), which holds 40 percent of the world market for wire bonders, which are used in chip assembly, despite its inability to crack the Japanese market. K&S responded to the challenge of Japanese rivals Kaijo Denki and Shinkawa in the U.S. market by focusing on the development of more innovative, higher-value-added products. K&S has also established leadership in rapidly growing non-Japanese Asian markets through investment in effective sales and support infrastructures.[84]

Technology and Manufacturing Trends

The Japanese semiconductor industry built its competitive advantage on high levels of investment and continuous improvement in manufacturing practices, which enabled higher yields and lower costs. By the mid-1980s, industry observers had noted a considerable gap in yields between Japanese and U.S. producers.[85]

U.S. device makers have put considerable effort in recent years into improving manufacturing performance and have made considerable progress. An ongoing study of semiconductor manufacturing performance by the University of California at Berkeley indicates

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[81] According to Dataquest data, Japanese equipment spending was almost double that of North America in 1990 and 1991. In 1994 the capital spending levels were about even.

[82] Several U.S. companies have also maintained a presence in DRAMs, including Micron Technology, Texas Instruments (in partnership with Hitachi), and IBM (in partnership with Toshiba and Siemens).

[83] Mark Crawford, "SVG Steamed Over Manassas Equipment Pacts," *New Technology Week*, August 12, 1996, p. 1.

[84] Neal Weinstock, "Coming Home: Why the Best Circuit-Board Equipment Is Made in the USA," *World Trade*, February 1995, p. 21.

[85] See U.S. Congress, General Accounting Office, *SEMATECH's Technological Progress and Proposed R&D Program* (Washington, D.C.: U.S. Government Printing Office, 1992), p. 10.

Box 5-2 The Impact of Market Access on Technology Investments

The impact of continued difficulties in accessing the Japanese market on the ability of U.S. companies to invest in technology development was discussed in the context of the semiconductor manufacturing equipment (SME) industry. Here are the steps for calculating how improved participation in the Japanese market might affect R&D spending in the U.S. SME industry at the margin:

1. According to VLSI Research, U.S. vendors held 53 percent of the roughly $17 billion global SME market in 1994, with sales of about $9 billion.[1] Japanese vendors held a 42 percent share, and European vendors accounted for just about all of the rest. Broken down by region, U.S. vendors maintained a 79 percent market share in the United States, a 24 percent share in Japan, a 48 percent share in Korea, a 59 percent share in Europe, and a 44 percent share in Asia Pacific markets outside Japan and Korea.

2. From the annual reports of 10 of the top public U.S. SME vendors, based on 1993 sales, U.S. companies are estimated to spend about 12 percent of sales on R&D.[2] If this is the case, 1994 R&D spending by U.S. vendors is estimated as about $1.1 billion.

3. Based on 1994 U.S. vendor sales of $1.15 billion in Japan, Japanese sales financed an estimated $140 million in R&D spending by U.S. vendors.

4. For 1994 each percentage point of market share in Japan was associated with about $50 million in sales for U.S. vendors and an estimated $6 million in R&D spending. For example, had U.S. vendors been able to capture 35 percent of the Japanese market in 1994 (11 percentage points higher than the actual result), it would have represented an additional $550 million in sales, which would be associated with an estimated $66 million in additional R&D spending by U.S. industry. A number of U.S. industry experts would argue that barriers to participation in the Japanese market prevent a higher level of sales for U.S.-based companies, leading to fewer resources for investment in R&D for next-generation equipment.

Although this estimation might be subject to biases in either direction, and is not intended as an overall model for R&D spending in this industry, it is a useful rough calculation of links between Japanese sales and R&D spending by one important high-technology industry at the margin. Expected accuracy could be improved with more complete data.

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[1] There are some differences between VLSI Research, Dataquest, and SEMI in estimating the total and regional markets. VLSI Research data were used here because market share by vendor nationality was provided.

[2] Based on a weighted average of corporate sales for Applied Materials, Asyst Technologies, Bio-Rad Laboratories, BTU International, Genus, KLA Instruments, Lan Research, Novellus Systems, Silicon Valley Group, and segment sales for Varian Associates. This group accounts for about one-fourth of U.S. SME industry sales. A number of the leading SME vendors are private or are divisions of larger companies, so estimating their SME-related R&D spending was not possible. Unless these vendors as a group spent significantly more or less than the public dedicated vendors on SME R&D, the estimate should not contain any particular bias.

that, while equipment and plant are of major importance, the biggest causes for differences in productivity between companies and fabs derive from differences in manufacturing practice and management.[86] The study has found considerable disparity in yields and productivity between fabs using similar processes and equipment. Although some caution should be used in interpreting the interim results because of the small sample size, the study indicates that Japanese semiconductor manufacturers, through utilizing superior manufacturing practices, still achieve higher manufacturing performance relative to U.S. and European fabs.[87]

The practices associated with superior fabs include (1) strong information systems capability to provide process control and the collection and analysis of data, (2) organizational capability focused on problem recognition and solving, (3) necessary internal technical talent and vendor support to implement improvements continuously, and (4) effective procedures for managing the introduction of new process flows. These practices are easier to implement in the Japanese context because of the human resource environment of Japanese companies and because of the characteristic close working relationships between equipment vendors and device makers, which were discussed above. A new emphasis that appears to be paying considerable dividends is a shift from total quality management to total preventive maintenance (TPM), or from perfect product to perfect machine.[88] The TPM approach emphasizes training to upgrade the skills of equipment operators so they are able to perform routine maintenance and deal with down equipment problems quickly.

In many areas of the SME market, U.S. companies have been able to maintain a technological edge in recent years and in some areas to extend it. Perhaps the best example is Applied Materials, which is now the largest SME vendor in the world.[89] The firm manufactures equipment for chemical vapor deposition, physical vapor deposition, epitaxial and polysilicon deposition, plasma etching, and ion implantation. Because of its superior technology and investment in an independent sales and service structure in Japan, sales in Japan have grown rapidly, in line with overall performance.[90]

The Contributions and Limitations of Technology Policy Solutions

A number of experts and industry leaders in the semiconductor and SME sectors agree that SEMATECH, a consortium of leading semiconductor device makers and the U.S. Department of Defense, has made a significant contribution to encouraging closer customer-supplier ties in semiconductor manufacturing. The consortium's experience also illustrates the limits of policy solutions focused solely on technology development in maintaining or restoring U.S. capabilities in critical areas.

Lithography has been a key area of focus for SEMATECH. In its five-year, three-phase program aimed at demonstrating .35-micron manufacturing processes by the beginning of 1993, the consortium worked closely with Geophysics Corporation of America (GCA) and Silicon Valley Group (SVG) to develop advanced steppers. In addition to R&D contracts with both companies in which SEMATECH funded research, collaboration with GCA included the

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[86] Robert C. Leachman, ed., *The Competitive Semiconductor Manufacturing Survey: Second Report on Results of the Main Phase* (Berkeley, Calif.: September 16, 1994).

[87] Ibid., p. 89.

[88] Ibid., p. 84.

[89] Applied Materials 1994 Annual Report.

[90] Between 1992 and 1994, overall sales of Applied Materials more than doubled, growing from $751 million to $1.66 billion. Japan sales doubled as well, growing from $227 million to $454 million. Sales in the Asia Pacific region outside Japan more than tripled, from $91 million to $301 million. Ibid.

purchase of a number of the firm's AutoStep 200 steppers for delivery to member firms for evaluation and joint development work.[91]

Despite successful development by GCA of the XLS 7000 and 7500 advanced steppers, judged by a number of industry observers to be superior to the latest generation of Nikon and Canon steppers, GCA succeeded in winning only one major production contract during the 1990-1991 investment period for sub-.5-micron processes. Potential customers, including many SEMATECH members, had doubts about GCA's viability as an ongoing concern. Because high-quality support for lithography equipment is essential to chipmakers, these doubts discouraged purchases from the U.S. firm. In 1993 GCA was shut down after several efforts to spin the firm off from its parent, General Signal, failed.[92] The case shows that even where public-private partnerships are successful in developing new technologies, ensuring a viable U.S.-owned and -based source for the technology may require additional steps to address market and business issues.[93]

An ironic and somewhat encouraging epilogue to the GCA story is provided by subsequent developments related to SVG's Micrascan II stepper. Although development of this tool involved some research funding by SEMATECH, the level of support was lower than was the case for GCA.[94] In May 1993, SVG announced plans for a 10-year agreement with Canon that would have given the Japanese firm access to step-and-scan technology that appeared to be increasingly key to its ongoing competition with Nikon.

Although at the time some observers argued that the SVG-Canon agreement, in combination with GCA's closure, would eventually spell the end of U.S.-owned and -based capabilities in advanced production steppers, the situation appears different as this is written. Throughout 1994 semiconductor device makers announced new plans for expanded capacity. In this more favorable market environment the Canon alliance, which had not yet been finalized, appeared to do for SVG what links with SEMATECH could not do for GCA—allay potential customers' concerns about long-term viability and access to service and support. During 1994, SVG booked orders of over $70 million for the Micrascan.[95] By the end of 1994, after over a year of negotiations, Canon and SVG ended their talks without reaching an agreement. However, SVG had booked enough orders to allow it to walk away from the agreement and not seriously impair its long-term prospects in the lithography business.

SEMATECH has announced that beginning in 1997 it will no longer require federal support. Its experience to date has illustrated several important lessons and highlighted unresolved questions about how U.S. public-private approaches to enhance U.S. competitiveness can be complicated by international alliance relationships. For example, as public-private supported R&D efforts move from the catch-up phase to the leading edge, there is likely to be greater concern about the distribution of benefits and proprietary advantage accruing from the results. The issue of foreign acquisition of SME companies that have worked extensively with SEMATECH has arisen in the past and may well again in the future.

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[91] GAO, *SEMATECH's Technological Progress and Proposed R&D Program,* op. cit., shows that of $287 million in external R&D spending by SEMATECH over the 1988-92 period, $108 million was spent on lithography.

[92] See Lucien P. Randazzese, "Semiconductor Subsidies," *Scientific American,* June 1996.

[93] In this case there were a number of options potentially available to government and industry had it been decided that keeping GCA afloat would advance significant U.S. interests. Under the Defense Production Act, government loans to GCA could have been arranged. Under Section 232 of the Trade Promotion Act, imported steppers could have been determined to endanger national security, and tariff protection for U.S.-produced steppers could have been arranged. At an earlier stage, SEMATECH and its members might have devised more explicit incentives to encourage member firms and other device makers to purchase GCA equipment.

[94] In addition to internal SVG and Perkin Elmer funding, IBM also invested in Micrascan development efforts.

[95] Silicon Valley Group, Inc., 1994 annual report.

Japanese industry and government appear to be learning lessons from SEMATECH as well. Several new public-private research programs have been launched in the past few years. With total funding of $190 million per year, these programs represent the largest-scale government-industry research effort in semiconductors since the 1970s.[96]

Outlook for 2007

• *The prospects for the U.S. SME industry will remain tightly linked to those of U.S.-based device makers. Due to its relatively small size and segmentation, the industry is likely to retain a more "national" character in terms of employment and technology base, compared with device makers that are increasingly global, and other industries examined in this report.*

• *Despite considerable gains by U.S. companies, the management of Japanese device makers and their relations with equipment suppliers still deliver a manufacturing edge. This is likely to persist in the future.*

• *The development of an independent Korean SME base and expanded cooperation between Korean, U.S,. and Japanese vendors are possible future trends.*

• *Although the U.S. industry is in a much better position than it was a few years ago, access to the Japanese market is still a concern of all but the strongest companies, and limited access to Japanese-owned fabs outside Japan may raise additional problems in the future. Given the sudden onset of unfavorable circumstances, the industry could find itself in deep trouble once again.*

• *SEMATECH appears to have facilitated better cooperation between U.S. device makers and SME vendors and can serve as a positive example for other industries, but the experience in lithography exposes the limitations of technology policy solutions in reestablishing a U.S.-based presence in key market segments.*

INFORMATION INDUSTRIES

The information industries sector is somewhat difficult to define precisely because of rapid technological changes, market growth, and structural shifts. Fast-moving innovations are blurring the lines between industries that have been considered the primary information-related sectors (such as telecommunications services, computer hardware, and computer software) and other industries such as entertainment, consumer electronics, and publishing.[97] Although the sector is so large and diverse that a comprehensive examination of U.S.-Japan competitiveness and technology trends would require an extensive study in itself, the Competitiveness Task Force

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[96] Kenneth Flamm, "Japan's New Semiconductor Technology Programs," Asian Technology Information Program Report 96-091, October 1996. In contrast with the United States, where civilian technology programs are extensively debated, the new Japanese programs and organizations were developed through government-industry consultation and coordination.

[97] See National Research Council, *Keeping the U.S. Computer and Communications Industry Competitive: Convergence of Computing, Communications, and Entertainment* (Washington, D.C.: National Academy Press, 1995) and Council on Competitiveness, *Endless Frontier, Limited Resources: U.S. R&D Policy for Competitiveness* (Washington, D.C.: Council on Competitiveness, 1996), p. 107. The latter report defines the information technologies sector as including telecommunications and networking equipment and services, computers, storage devices, terminals, peripheral equipment, software and associated services, office machinery, packaged software, data processing, information services, facilities management, and other associated services.

reviewed several key issues that have broader implications for the overall U.S.-Japan science and technology relationship.

Computers, Software, and the Development of U.S. and Japanese Capabilities

Most of the industries and technologies underlying the ongoing "information revolution" were pioneered in the United States, and U.S. institutions and companies still enjoy widespread leadership in research and commercialization.[98] U.S. leadership was forged and extended during the Cold War period, with U.S. policies and market factors spurring technology development and diffusion, particularly in the areas of computer hardware and software.[99] The U.S. government invested large amounts in computer and communications research and education, leading to the emergence of a broad human resource base for research and commercialization. The government was also a lead user of advanced information systems and enabling technologies, such as the SAGE air defense system in the 1950s and the space program in the 1960s, and promoted the diffusion of knowledge through its research support and antitrust policies. By the 1960s, a growing commercial market for data-processing equipment and services had emerged, and U.S. companies, most prominently IBM, had established themselves as the market and technological leaders. The mainframe computer was the central product, and business demand drove market growth.

The Japanese government and the integrated Japanese electronics firms were aware of the significance of mainframe computers from an early date. A catch-up strategy was developed, with one key priority being to control market participation by IBM and other foreign vendors while promoting the transfer of critical technologies. A government-subsidized leasing company was set up to match IBM's marketing edge, which lowered market risks for hardware makers and stoked demand for mainframes and data-processing services. A series of government-industry collaborative R&D projects was designed to strengthen the domestic technology base and eventually establish Japanese leadership in innovation.[100]

This strategy, combined with the decision by two of the three Japanese computer companies to adopt IBM-compatible architectures, was quite effective for a number of years. The Japanese computer makers were able to build sufficient capabilities to meet the needs of domestic users and gradually closed much of the technology and market gap with IBM and other U.S. companies. By the mid-1980s, Japan's IBM-compatible mainframes were competitive, and the Japanese computer industry was making important inroads in supercomputers. At the same time, spillovers between U.S. government computer procurement in defense and other areas and the fastest-growing commercial sectors had become less common. It began to appear that U.S. companies had to take Japanese competition seriously and that Japanese strength in associated components such as logic circuits, memory, and storage devices would allow the Japanese computer industry to compete effectively, while government-industry collaborative research programs such as the Fifth Generation Computer Project would establish technological leadership.

Several technological and market developments prevented this from happening. Continuing rapid innovation led to dramatic improvement in the cost performance characteristics of data

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[98] U.S. industry accounts for about half of global revenues in these sectors. Council on Competitiveness, op. cit.

[99] See Richard N. Langlois and David C. Mowery, "The Federal Government Role in the Development of the U.S. Software Industry," in David C. Mowery, ed., *The International Computer Software Industry: A Comparative Study of Industry Evolution and Structure* (New York: Oxford University Press, 1996).

[100] Marie Anchordoguy, *Computers, Inc.: Japan's Challenge to IBM* (Cambridge, Mass.: Harvard University Press, 1989).

processing equipment during the 1970s and 1980s. With the advent of the minicomputer, workstation, and particularly the personal computer, the market for computers grew from its base in large businesses and government agencies to include a wider range of organizations and eventually individuals. Just as the Japanese computer industry was catching up with IBM and Cray, the center of gravity for information technologies markets shifted dramatically toward distributed computing, the development of packaged applications software for open architectures, and more recently to new business and entertainment applications enabled by the Internet.[101]

In this environment the continuing advantages of the U.S. system, including a strong human resource and university research base, financial institutions well adapted to support investment in the commercialization of new technologies, and most importantly an open and dynamic market for information technology products, have enabled innovative U.S. technologies and firms, both new and established ones, to flourish. In the case of key technologies such as the MS-DOS operating system and Intel's microprocessor architecture, a strengthening of U.S. intellectual property protection and the emergence of these products as de facto standards put U.S. firms in a stronger position than past U.S. innovators, such as RCA (in color television) and Fairchild (in basic semiconductor production technologies), which had been forced to license key technologies to Japanese industry in return for market access in the 1950s and 1960s.[102] By contrast, the PC standards developed by Japanese companies remained fragmented and incompatible, the price performance characteristics of Japanese PCs did not improve as quickly as the U.S.-determined global standard, and the technology did not diffuse quickly within Japan until recently.

Structural features of the Japanese system, several of which provide sharp contrasts to characteristics of the U.S. system, also have hindered overall Japanese progress in information industries. Japan's strategy of utilizing government-industry cooperation to encourage inward technology transfer while developing domestic industry strengths has proven difficult to pursue effectively in the rapidly growing and largely unregulated markets centered on PCs. The government-industry collaborative R&D programs of the 1980s focused on several areas of information technology considered critical at the time, but these either failed to reach their technical goals or shifts in markets and participating company strategies rendered them irrelevant before they were completed.[103] Japan lacked the education and advanced research base, financial infrastructure for commercializing new ideas, and dynamic open markets in information technology that pushed innovation in the United States. Japan's lower emphasis on software and its different approach to software development, described below, also have played a major role.

Finally, the patterns of globalization pursued by U.S. and Japanese companies also have had an impact. In the late 1980s it appeared that the collective strength of Japanese companies in many areas of computer hardware would be leveraged to gain greater control over global information technology markets. However, competition from companies based in Asia in

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[101] National Research Council, *Realizing the Information Future: The Internet and Beyond* (Washington, D.C.: National Academy Press, 1994), Appendix A, contains a primer on the development and key features of the Internet. See also National Research Council, *Evolving the High-Performance Computing and Communications Initiative to Support the Nation's Information Infrastructure* (Washington, D.C.: National Academy Press, 1995).

[102] It should be pointed out that the relationship between intellectual property protection, industry structure, and innovation are complex, particularly in these industries. Strong intellectual property protection encourages innovation, but may also contribute to the emergence of an industry structure that discourages new entry. Therefore, the impacts and interaction of intellectual property policy and competition (antitrust) policy are very important. See Robert P. Merges, "A Comparative Look at Intellectual Property Rights and the Software Industry," in Mowery, ed., op. cit.

[103] The MITI-led Fifth Generation and Supercomputer consortia, and the Ministry of Education, Science, and Culture-led TRON project are relevant here. These are described by Scott Callon in *Divided Sun: MITI and the Breakdown of Japanese High-Tech Industrial Policy* (Stanford, Calif.: Stanford University Press, 1995). As pointed out in other parts of the report, however, these programs probably produced less tangible benefits in the form of training and improved research infrastructure.

hardware products created alternative sources for critical components. Different approaches to direct investment in Asia by U.S. and Japanese companies were largely responsible for this turn of events.[104] U.S. electronics investments in Asia have been aimed at the U.S. and global markets and have transferred significant capabilities to Asian manufacturers. This has created an alternative supply base and competition for Japanese firms. In contrast, Japanese investments in Asia have until recently tended to focus on local markets and to transfer less sophisticated products and processes.

Current Capabilities and Trends

As a result of their disparate development paths and institutional legacies, Japanese and U.S. information technology markets and capabilities are quite different. Several aspects of Japanese industry approaches and business practices are currently seen as disadvantages. The first is the lower level of diffusion of information technologies, particularly PCs, relative to the United States. Figure 5-1 shows trends in U.S. and Japanese investments in information-related products. Despite accelerated growth in recent years, Japan still lags the United States in the diffusion of PCs, particularly networked PCs used in business.[105]

Another characteristic of Japanese information industries is a relative emphasis on the development of custom versus packaged software. Experts have noted Japanese strength in developing customized software and the advantages of the "software factory" as an organizational tool.[106] However, the Japanese capability to produce custom software for proprietary systems represents the flip side of a dearth in capability to develop packaged applications software for open systems.[107] According to one estimate, over 60 percent of Japan's total 1990 software production was accounted for by a combination of users' in-house capabilities and software houses spun off from, and still closely associated with, users.[108]

Japanese demand is likely to shift toward packaged software as distributed processing becomes more widespread. For Japanese users the cost differential between maintaining large investments in unique solutions (run mainly on mainframes) and switching to standardized solutions (run mainly on distributed open systems) is growing as the U.S. packaged software industry has grown more innovative. Adaptation of foreign-developed applications to run on Japanese systems also is becoming less expensive. A key turning point was the development of the Japanese version of Microsoft Windows, which has spurred rapid growth in the Japanese PC market and is spelling the demise of the closed proprietary PC standards maintained by Japan's leading computer manufacturers.

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[104] See Michael Borrus, "Left for Dead: Asian Production Networks and the Revival of U.S. Electronics," in Eileen Doherty, ed., *Japanese Investment in Asia* (Berkeley, Calif.: The Asia Foundation and Berkeley Roundtable on the International Economy, 1995).

[105] According to a projection by IDC Japan, the diffusion rate of PCs in U.S. business will be close to 60 percent, versus 25 percent or so in Japan. About 90 percent of U.S. business PCs are expected to be networked, versus just under 50 percent in Japan. See *Nihon Keizai Shimbun*, July 22, 1996, p. 34.

[106] Michael A. Cusumano, *Japan's Software Factories: A Challenge to U.S. Management* (New York: Oxford University Press, 1991).

[107] William V. Rapp and Hugh T. Patrick, *The Future Evolution of Japanese-U.S. Competition in Software: Policy Challenges and Strategic Prospects*, Report to the Japan-U.S. Friendship Commission, August 1995.

[108] Yasunori Baba, Shinji Takai, and Yuji Mizuta, "The User-Driven Evolution of the Japanese Software Industry: The Case of Customized Software for Mainframes," in Mowery, ed., op. cit.

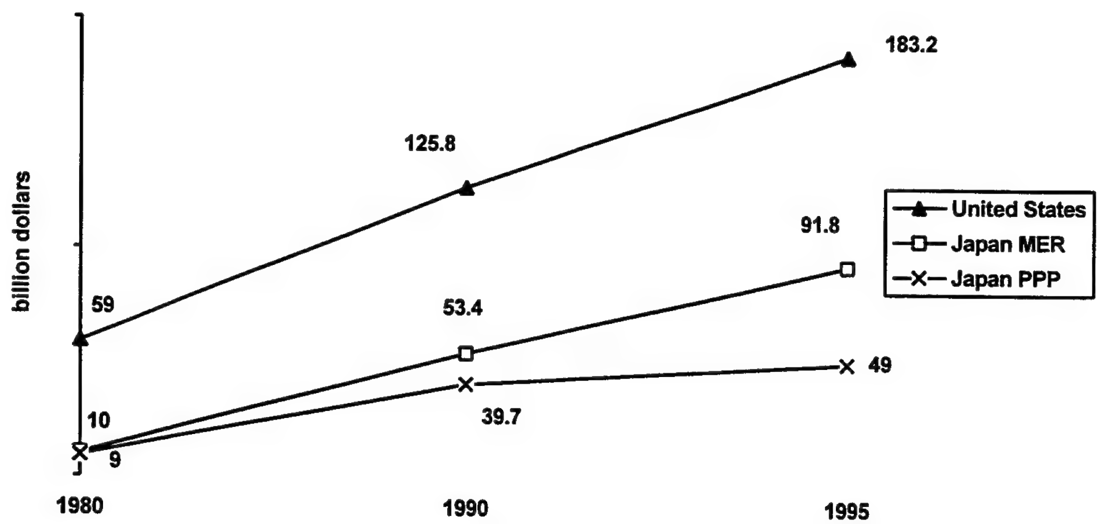

FIGURE 5-1 Information-related investment. NOTE: PPP (purchasing power parity) and MER (market exchange rates) from Organization for Economic Cooperation and Development. SOURCE: *Nihon Keizai Shimbun*, July 22, 1996, p. 34.

Today, Japanese companies are largely absent from the packaged software market, including operating systems as well as the most important and rapidly growing application segments for businesses and consumers such as groupware, Internet browsers, and relational databases.[109] Japanese companies are only now beginning to develop strategies for the Internet and "intranets" that link corporations. However, it would be a mistake to make too much of these relative weaknesses or to downplay Japan's strengths. Japanese companies remain quite strong in significant areas of information technologies. These include computer and video games, high-value-added hardware components of information systems (displays, optical storage), embedded software in products such as numeric control software for machine tools, and vector supercomputers. In these areas, differences in the structure of the Japanese market have not constituted a disadvantage. For example, fragmented standards have not been a major barrier to the diffusion of "stand-alone" systems like games and machine tools.[110] The needs of supercomputer users are usually highly specialized, with applications software developed in-house or by contractors, so purchasing decisions are largely determined by price and hardware capabilities.

Japanese companies and the Japanese government are also taking steps to adapt and become more competitive. For example, anecdotal evidence indicates that the large Japanese electronics companies are maintaining their investments in longer-term research and expanding their collaborative work with Japanese universities.[111] Recent Japanese policy initiatives are aimed at

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[109] As of June 1996, 85 percent of the 20 top-selling software packages in Japan were localized versions of foreign programs. See John Boyd, "The Past, Present, and Future of Japanese Software," *Computing Japan*, June 1996.

[110] However, the PC is even mounting a strong challenge in numeric controllers. See Steve Glain, "PCs Undercut Top Factory-Robot Maker: Fanuc of Japan Sees Its Market Clout Slipping Away," *The Wall Street Journal*, May 20, 1997.

[111] For example, a group of 21 Japanese univerisities and 10 electronics companies, including foreign capital companies such as Texas Instruments and IBM, announced plans for a four-and-a-half-year, 1 billion yen research

promoting the diffusion of information technologies and strengthening the university research base—areas where Japan is weak relative to the United States.[112] In addition, Japanese companies have responded very rapidly and aggressively to the competitive challenges of the past few years, such as the assault on the Japanese PC market by Compaq and others, by rapidly globalizing their sourcing patterns. NEC, Fujitsu, and others are now positioned to reenter the U.S. PC market, which they had largely abandoned in the late 1980s.

There are also signs that the business culture in Japan is changing. One company that is pursuing a very different strategy toward information industries than other Japanese firms is Softbank Corporation. From its base in Japan as a software and peripherals distributor, Softbank has concluded a broad and dynamic array of acquisitions, minority investments, and strategic alliances, mainly involving U.S. firms, in the past several years (see Table 5-4). In contrast to traditional Japanese corporate strategies in this industry, which are focused on hardware, inward technology transfer, and catching up with U.S. front-runners, Softbank has moved to establish a dominant position in key areas of the infrastructure for information businesses, such as publishing and information technology trade shows. Also, a number of Softbank's alliances appear to be aimed at facilitating access by small- and medium-sized U.S. technology start-ups to the Japanese market. Softbank's ultimate degree of success remains to be seen, but the existence of a maverick Japanese firm pursuing high-risk strategies raises the possibility that U.S.-Japan cooperation and competition in this sector will be different than in the past. Although Softbank is something of an outlier in the Japanese context, Japanese companies are increasingly willing to engage in reciprocal relationships with U.S. partners, particularly in this industry.[113] By the same token, some U.S. software firms are aggressively investing in Japan, as illustrated by Intuit's acquisition of Milky Way, a small Japanese software company, in 1996.

Despite current leadership in this industry by U.S. firms, particularly in establishing the most important information technology architectures and standards, U.S. advantages should not be overstated or taken for granted. For example, despite global market leadership by U.S. companies, the U.S. trade balance in information technology products moved from a small surplus in 1990 to a $20.9 billion deficit in 1994.[114] Also, it appears that U.S. industrial R&D in these industries is increasingly focused on product development, while longer-term corporate R&D has been reduced.[115] Events of the past decade show that today's winners in information industries can quickly become tomorrow's losers.[116]

effort in the area of parallel computing. See "San-Gaku kyodo de sentan kenkyu" (Advanced Industry-Government Research), *Nihon Keizai Shimbun,* October 2, 1995, p. 17.

[112] See Government of Japan, "Science and Technology Basic Plan," July 2, 1996.

[113] One important example was Hitachi's decision to purchase microprocessors for its mainframe computers from IBM. "Hitachi Turns to IBM, Eyes Power PC," *Electronic Engineering Times,* May 2, 1994, p. 14.

[114] Council on Competitiveness, op. cit., p. 109.

[115] See Ibid., p. 107. There is some debate among experts about the extent and significance of this trend.

[116] For example, a significant market shift from PCs to the emerging "network computer" could lead to new opportunities for Japanese firms.

TABLE 5-4 Selected Recent Softbank Acquisitions, Minority Investments, and Strategic Alliances

Partner	Form of Partnership	Business
Interactive Marketing	minority investment	computer trade shows, publishing
Yahoo!	minority investment	on-line services
Ziff-Davis Publishing	acquisition	publishing
Comdex	acquisition	computer trade shows
CyberCash Inc.	minority investment	on-line services
Unitech Telecom	minority investment	telecommunications
Microsoft	joint ventures	games
NTT	joint venture	on-line services
Decisive Technology Corp.	minority investment	on-line services
Kingston Technology	acquisition	memory boards
I-Search	minority investment	on-line services
Phoenix Publishing Systems Inc.	acquisition	publishing
Firefly Network Inc.	minority investment	on-line services
I/Pro	minority investment	on-line services
US Web	minority investment	on-line services
Trend Micro	minority investment	on-line services
Live World Productions	joint venture	on-line services
Chase Manhattan	joint venture	internet investments
Time Warner/Intel	joint venture	on-line services
Verisign	minority investment	on-line services
News Corp.	joint venture	digital satellite television
Iota Industries	minority investment	document search software
Tabula Interactive	minority investment	on-line services
Asymetrix	minority investment	on-line services
Sega	joint venture	publishing
Dentsu	joint venture	advertising

SOURCE: Compiled by Office of Japan Affairs from news reports.

Future Questions and Issues

Market Dynamism

The dynamic, rapidly growing U.S. market for information technology products will continue to be a strong force in driving innovation. One important question for the future is whether the Japanese market will come to play a similar role. Japan's competitive, dynamic market plays an important role in pushing new technology in areas such as consumer electronics and games. Despite the fact that Japan's markets in computing and communications are somewhat more open

and competitive than they were a few years ago, cost levels and regulatory barriers are still significantly higher than those of the United States (see Figure 5-2).[117]

Telecommunications services are particularly important. In contrast to the United States, where deregulation and the break-up of the Bell System has led to increased competition and lower costs, the Japanese market is still highly regulated. NTT still holds a dominant position in providing long distance and local service, and costs are still several times higher than in the United States. With the implementation of new legislation in 1996, the U.S. approach is moving further toward deregulation and open competition. Meanwhile, debate in Japan over deregulation of telecommunications markets and restructuring NTT has focused on how changes would

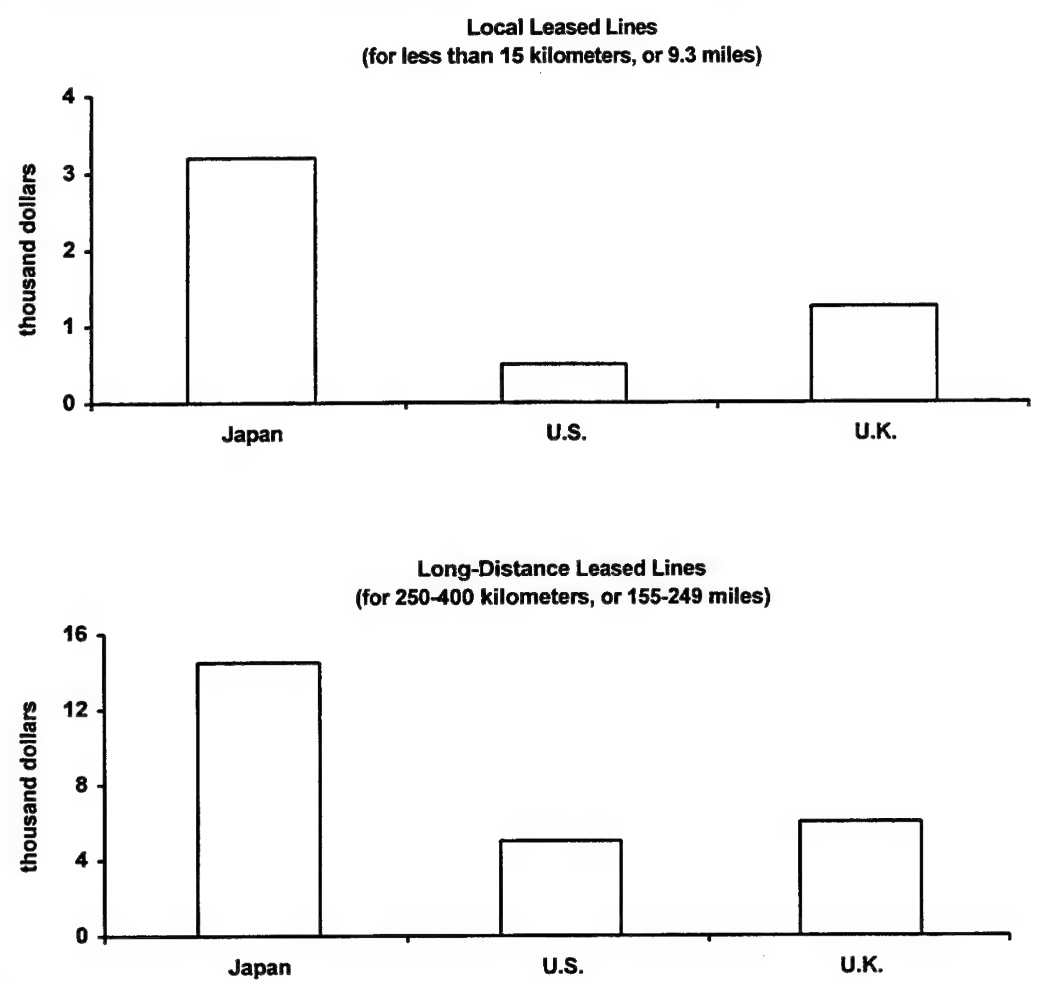

FIGURE 5-2 Annual cost of leased-line service for 1.5 Mbps service. SOURCE: Goldman Sachs & Co., as compiled in *The Wall Street Journal*, February 14, 1996, p. A10.

[117] Some observers also believe that Japan's business culture will hinder utilization of information technology in industry. See "Wiring Corporate Japan," *The Economist*, April 19, 1997.

impact international competitiveness.[118] In December 1996 the Japanese government announced plans to divide NTT into three operating divisions, owned by a single holding company.[119] Nevertheless, however Japan's policies and strategies change in coming years, it is very unlikely that a U.S.-style approach emphasizing openness and free competition will be instituted in the near future.[120]

Asian Markets and Technology Networks

Asian markets and technology networks will also play an increasing role in information technologies. The Asian market for personal computers, for example, is expected to grow by 20 to 30 percent a year until the end of the century.[121] This growth presents significant opportunities and challenges for U.S. and Japanese companies. Although the Asian electronics production networks of U.S. and Japanese companies have served as valuable suppliers, balancing short-term demands for technology transfer and the longer-term risk of creating new competitors is a growing challenge.[122] Asia will increasingly serve as a source of innovation and technology as well. Both U.S. and Japanese companies have been active in building R&D capabilities in Asia.[123]

As in regulation, U.S. and Japanese approaches to Asian markets and innovation show significant differences. The U.S. government tends to pursue liberalization in trade and regulation both bilaterally and through multilateral organizations.[124] U.S. companies pursue their own strategies for accessing Asian markets and technological capabilities. The approach of Japanese government and industry to the Personal Handy-Phone System (PHS) is instructive by way of contrast. PHS is a digital mobile communications system developed collaboratively by the Ministry of Posts and Telecommunications and the private sector.[125] NTT is now making aggressive efforts in Asia, including R&D cooperation, to establish PHS as an international standard to compete with cellular technologies.[126] This is just one example of the comprehensive Japanese government and industry approach to science and technology cooperation in Asia.[127]

For the United States, balancing the long- and short-term interests of individual companies and the U.S. economy as a whole in trade and technology relationships with Asia will continue to be a challenge. Some experts assert that Japanese investment in Asia, particularly in electronics, represents a shift in the U.S. trade deficit with Japan to a deficit with Asia.[128]

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[118] "Kenkyu kaihatsu ryoku ne genkai" (Limitations on R&D Capability), *Nihon Keizai Shimbun*, September 14, 1995, p. 3.

[119] "Global Competitors Have Little to Fear in NTT," *Reuters Yahoo! News*, December 6, 1996.

[120] Steven K. Vogel, *Freer Markets, More Rules: Regulatory Reform in Advanced Industrial Countries* (Ithaca, N.Y.: Cornell University Press, 1996).

[121] "The East Is Wired," *Far Eastern Economic Review*, June 15, 1995, p. 71.

[122] "Price of Entry into China Rises Sharply," *The Wall Street Journal*, December 19, 1995, p. A14.

[123] "Ajia de kenkyu kaihatsu kyoka" (Strengthening R&D in Asia), *Nihon Keizai Shimbun*, February 6, 1995, p. 8.

[124] "Pacific Rim Nations Pledge Tariff Cuts: Clinton Wins Accord on High-Tech Goods," *The Washington Post*, November 26, 1996, p. 1.

[125] "Japan's Personal Handy-Phone," *Asia Technology Information Program Report 95-26*, May 1995.

[126] "NTT Singapore Representative Office," Description of activities, *NTT World Wide Web Homepage*.

[127] National Science Foundation Tokyo Office, "Japan's Technical Cooperation with Asian Countries," NSF Tokyo Office Report Memorandum 96-17, July 1996.

[128] For example, Kozo Yamamura and Walter Hatch, "A Looming Entry Barrier: Japan's Production Networks in Asia," National Bureau of Asian Research, February 1997; Mitchell Bernard and John Ravenhill, "Beyond Product Cycles and Flying Geese: Regionalization, Hierarchy, and the Industrialization of East Asia," *World Politics*, January 1995; and Mark Z. Taylor, "Dominance Through Technology: Is Japan Creating a Yen Bloc in Southeast Asia?", *Foreign Affairs*, November/December 1995.

Investments in R&D

Federal spending on basic research, advanced education, and leading applications of information technology have played an important role in U.S. leadership in information technologies.[129] The High Performance Computing and Communications Initiative, an interagency initiative of the federal government, continues the tradition of strong federal support and has contributed to the development of technologies that have advanced U.S. competitiveness in information technologies, such as the Mosaic Internet browser.[130] At the same time, the lack of a strong fundamental research base and advanced computer science and engineering training has been seen as one of Japan's primary weaknesses. As noted above, U.S. and Japanese investment patterns are changing in this industry. The U.S. federal government faces budget pressures, that will likely constrain overall R&D spending, and reductions in Department of Defense support for some areas of computer science R&D are already perceived to be having an impact.[131] Meanwhile, the Japanese government is working to build a stronger fundamental research base. At this point, it is still difficult to predict the impact of these trends.

Intellectual Property Protection

As noted above, stronger U.S. intellectual property rights laws and enforcement have been an important factor in maintaining U.S. leadership in information technologies, particularly in setting the most important de facto standards and architectures. Since the United States is likely to remain the leading market for information technology products, and possession of a U.S. patent allows exclusion of infringing products, U.S. intellectual property rights laws are in many cases sufficient to discourage illegal copying and patent or copyright infringement efforts. A nascent Japanese plan to amend its copyright laws to allow unrestricted software decompilation, which might have allowed Japanese firms to reverse engineer U.S. software and market the copied product, was dropped after protests by the U.S. government and U.S. industry.[132] U.S. government and industry criticism also caused Japanese standards-setting officials to drop plans for software quality standards that could have evolved into trade barriers.[133] Indeed, the U.S. software industry is very active in pursuing its collective policy interests in Japan and other markets.

Protection from copyright infringement in the area of pirated products is another important issue.[134] In this area, U.S. and Japanese interests may be moving toward greater confluence. For

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[129] For an overview of the status and prospects of U.S. computer science and engineering, see National Research Council, *Computing the Future: A Broader Agenda for Computer Science and Engineering* (Washington, D.C.: National Academy Press, 1992).

[130] HPPCI a multi-agency initiative that serves as the main vehicle for public research in information technology. It was established in 1991 to (1) extend U.S. leadership in high-performance computing and networking, (2) disseminate new technologies to serve the economy, national security, education, health care, and the environment; and (3) spur gains in the U.S. economy. See National Research Council, *Evolving the High-Performance Computing and Communications Initiative to Support the Nation's Information Infrastructure,* op. cit. The NRC assessment credits HPPCI with a number of accomplishments, and recommends several modifications in the program.

[131] U.S. Department of Commerce, Bureau of Export Administration, *Critical Technology Assessment of the U.S. Artificial Intelligence Sector*, 1994).

[132] U.S. Trade Representative, *1995 National Trade Estimate* (Washington, D.C.: U.S. Government Printing Office, 1995), and Japan Economic Institute, *JEI Report 22B,* June 10, 1994.

[133] Japan Economic Institute, *JEI Report 33B,* September 1, 1995.

[134] One difficulty sometimes encountered in enforcing copyright infringement in Japan is the long delay encountered in obtaining search warrants. Japanese police also complain of these delays. See Miyazawa Setsuo, *Policing in Japan* (Albany, N.Y.: SUNY Press, 1992), p. 90.

example, Japanese companies that are victims of piracy are increasingly willing to pursue legal action to protect their rights.[135] At the policy level, the Japanese government has been much less vocal than the U.S. government in pressing copyright issues with China and other developing countries, but has also embarked on a focused effort to cooperate with Asian countries as they develop their intellectual property protection systems.[136] In the future it may be possible for the United States to work more closely with Japan and other producers of intellectual property to ensure that patents and copyrights are protected in Asia.

Outlook for 2007

- *Japan's research base in industry and at universities is likely to become stronger and more important to the global shape of these industries. As was the case in mainframes and vector supercomputers, Japanese companies are likely to narrow the gap in parallel architecture, workstations, PC development, and perhaps even in software. Future market shifts, such as the rise of network computers that replace the PC, also could provide new opportunities for Japanese companies.*
- *Both U.S. and Japanese-based information products manufacturers are likely to move more manufacturing offshore. Asian countries will increasingly be the source of components and subassemblies. Some Asian countries could also become the source of engineering development for multinational corporations, as India is today in some areas of software.*
- *These trends will result in further intensification of global competition, resulting in consolidation, exit of weaker companies, emergence of important new Asian companies, and market share shifts between companies and countries that cannot be foreseen at this point.*

[135] "Japanese Games Publishers Team to Fight Piracy," *Newsbytes Pacifica Headlines*, December 6, 1996.
[136] Japan Economic Institute, *JEI Report 3B*, January 24, 1997.

6
Key Lessons and Priorities for the United States

WHAT HAS CHANGED AND WHAT HASN'T?

From examination of the historical context for technology and economic development in the United States and Japan and recent trends at the national and industry levels, the Competitiveness Task Force identified major areas in which important changes have occurred or are occurring, and others where earlier patterns are likely to persist. Table 6-1 summarizes the task force's judgments.

Issues for Japan

Barriers to Participation in the Japanese Market and Impacts

Japanese government and industry no longer exercise the most potent policy tools to extract technology from foreign companies as a price of market entry, particularly control over trade and foreign direct investment. Overall, progress toward more open markets in Japan has accelerated in recent years, particularly consumer markets, as appreciation of the yen and other factors opened a significant value gap between goods produced in Japan and those produced abroad for many industries. Many U.S.-based and other foreign companies are taking advantage of new opportunities to expand market participation.[1]

Although the trend is moving in the right direction, the pace and degree of market opening vary widely depending on the industry. Particularly in critical sectors where sales are made to companies rather than consumers, such as automotive components and semiconductor manufacturing equipment, market barriers are still an issue. In some industries the Japanese policy environment in regulation, competition policy, intellectual property protection, and other areas still serves to prevent U.S.-based companies from fully participating in the Japanese market. Much of the rise in Japan's manufactured imports has been due to products manufactured in Asia by Japanese firms.

However, in the opinion of the task force, Japan's closed markets in high-technology industries where innovation is occurring most rapidly have stunted competition and innovation. In areas where the domestic market is protected and does not drive competition and innovation, barriers to foreign and domestic entrants may do more harm to Japanese industry than to U.S. and other foreign-based competitors.

Impact of New Players

The rapid growth of Asian economies and the emergence of Asian companies as important new players in high-technology development and manufacturing will have a significant impact on

[1] The more recent appreciation of the dollar has slowed this process in particular industries.

TABLE 6-1 Evolution of U.S.-Japan Science and Technology Relations and U.S. Competitiveness

	Past	Present	Future
Scientific and Technological Capabilities	• The United States was preeminent in most areas, driven by defense needs. • Japan's capabilities expanded rapidly, particularly in applied fields linked to growing industries.	• U.S. capabilities remain formidable, with focus on commercialization and diffusion; improvement spurred by Japanese competition. • Japan has reached parity or near parity in many key fields but capabilities are unbalanced; investment in nonproprietary R&D by government has been low.	• Japan follows through on goal to significantly increase public spending on basic R&D, exceeding U.S. per capita spending. • The U.S. R&D enterprise restructured to fit post-Cold War and budget balance realities. • Both countries refine approaches to public-private partnerships and international cooperation.
Policy and Corporate Strategy Focus	• For Japan: catch up/reduce dependence through technology acquisition, target resources to manufacturing industries, producer-focused economy. • For the United States: maintain defense technology lead; maintain strong basic science and research base; consumer-focused economy.	• For Japan: develop greater strength in fundamental research; globalize corporate technology capabilities; new policy approaches to catch up in information-related fields. • For the United States: reinvigorate manufacturing; greater market and global focus for companies.	• For Japan: defensive and protective action increasing as new competition emerges in Asia? • For the United States: pursue global IPR protection to ensure returns on R&D investment; more aggressive trade policies?

TABLE 6-1 continued	Past	Present	Future
U.S.-Japan Science and Technology Transfer Relationship	• The relationship has been one-sided, with science and technology knowledge flowing predominantly to Japan. • Barriers to trade and investment were effective tools for Japan in facilitating technology acquisition. • The United States was not prepared to access Japanese technology.	• Bilateral technology flow is still unequal, but patterns and balances have changed. • Japan has less scope to use market access barriers to acquire key U.S. technologies. Effectiveness of new mechanisms uncertain (sponsoring U.S. university research, launching foreign R&D laboratories). • The United States has developed limited capabilities to access Japanese technology.	• Bilateral flows of technology likely to remain uneven, but more partnerships will be characterized by comparable contributions. • Renewed Japanese investment (mainly in information sectors) in foreign R&D reflects an expectation that new mechanisms will pay off. • U.S. opportunities to access Japanese technology will depend on market access and the level of scientific and engineering research done in nonproprietary settings.
Competitiveness Impact and Situation	• Technologies transferred from abroad were a key ingredient in Japan's rapid ascent as a techno-industrial superpower. • Japanese firms took advantage of U.S. complacency.	• Japanese competition has benefited U.S. companies and industries; the United States has adapted Japanese management, employee relations and partnership strategies. • Japanese competitiveness gains vis-à-vis the United States have slowed and in some cases been modestly reversed.	• U.S.-Japan competition will be affected by new players, especially in Asia. • Information industries will continue to be a key area for U.S.-Japan cooperation and competition. • U.S. gains are real and sustainable, but complacency and renewed efforts by Japanese government and industry will pose challenges.

the U.S.-Japan relationship. Technology investments and technological capabilities are growing rapidly across Asia. Both U.S. and Japanese companies face challenges as they try to access Asian markets while managing the risks of creating future competitors through technology and production transfers. There is evidence that they are taking different approaches. In the automobile industry, for example, suppliers of Japanese automakers are inclined to invest as a coordinated group, while U.S. companies are not. Although their ultimate impact can be debated, the task force believes that Japanese government and industry economic strategies toward Asia are much more systematic and coordinated than are those of the United States.

Scientific and technological relations with Asian countries, including competition and cooperation with Japan in a broader Asian context, will increasingly affect U.S. and Japanese innovation capabilities. There are several contrasting visions for the future. According to one, Japanese companies and government are pursuing a coordinated strategy to achieve a preeminent position in a number of emerging Asian markets. If they are successful in establishing a Japan-dominated Asian manufacturing and market base from which competitively priced manufactured goods flow to the rest of the world and which largely excludes non-Japanese foreign influences, this would expand and extend Japan's ongoing economic imbalances with the rest of the world to an Asian problem.

According to another formulation, whatever strategies Japanese companies and government are pursuing, it will be difficult for them to dominate the emerging Asian economic powerhouse. Growing Asian technological and manufacturing capabilities will create greater competition for Japan-based firms in a number of areas. This trend has already benefited the U.S. electronics industry, as Asian production networks broke the stranglehold of Japanese companies in the supply of a number of critical components, depriving the Japanese industry of leverage with which to compete with U.S. leaders in higher-value-added areas.

Japanese Responses

Japanese industry and government are responding to these challenges in a number of ways. In automobiles, semiconductors, and other manufacturing industries, Japanese companies have moved many manufacturing activities to Asia, the United States, and elsewhere and have redoubled continuous improvement efforts to ensure that critical manufacturing tasks can be performed in Japan at competitive costs while recognizing flat domestic demand and possible broad swings in exchange rates. Japanese companies continue to aggressively pursue global markets in industries where they have experienced failure in the past, such as personal computers. Although Japanese companies have less ability to invest in long-term research and other capabilities than was the case during the bubble years, corporate governance and financial systems still appear to allow a longer-term view than is typically true of U.S. companies.

Japanese companies are continuing to develop new approaches to tap foreign technological capabilities. For example, 1995 saw a renewed interest in Japanese investments in U.S. R&D facilities, particularly in information industries. In biotechnology, Japanese companies have invested in partnerships with small U.S. biotechnology firms to build their in-house capabilities and utilize biotechnology as an avenue to compete in global health care and agriculture markets. Experts point out that Japanese research capabilities and technological sophistication in this area, both in research institutes and in companies, has grown considerably over the past decade.

In addition to the competitive responses of companies, Japanese government and industry are attempting several systemic changes to bolster national capabilities in fundamental research and new technology-based industries. The Science and Technology Basic Law of 1995 and the Science and Technology Basic Plan of 1996 call for large increases in public spending on

research and development and institutional reforms to create a research environment more conducive to fundamental work. In critical industries such as semiconductors, government and industry have launched new national technology development programs to boost long-term competitiveness. Some limited steps also have been taken to increase incentives for investing in technology-based start-up companies. Although the results of these changes are not certain, taken together they represent a significant and focused national effort to maintain Japan's place at the forefront of global high-technology industries.

Issues for the United States

Narrowing but Persistent Manufacturing and Product Development Gaps

U.S. companies in a range of industries have clearly responded to the challenge of Japanese competition over the past decade. This has contributed to the improved competitiveness of the U.S. economy as a whole. In the automobile industry, for example, this has involved improved performance in both manufacturing and product development to close the gap with Japanese companies. As a nation, the United States has pursued a successful decentralized effort over the past decade to better understand Japan and pursue effective interactions. However, in automobiles, semiconductor devices, and other manufacturing industries, Japan still has a manufacturing edge.[2] U.S. manufacturers, including Japan-based companies manufacturing in the United States, will need to continue to improve in order to avoid falling significantly behind the Japanese and in some cases Asian economies in the future.

In the opinion of the task force, how well the United States addresses fundamental challenges such as improving K-12 education and raising savings rates—issues outside the scope of this report—will play a large part in determining whether the U.S. economy will continue to make progress in manufacturing performance and competitiveness.

Continued Strength in Fundamental Research, With Future Uncertainties

Much of the U.S. industrial and competitive resurgence of recent years has been based on continued strength in fundamental research and market-driven innovations. The United States still produces the lion's share of technological innovations with significant commercial implications and remains the premier location for research and innovation.

Concerns have been raised that Japanese and other foreign companies are siphoning U.S. innovations through investment in U.S. high-technology companies, links with U.S. universities, and establishing U.S. R&D laboratories.[3] The flip side of this concern is the fact that these investments demonstrate, and to some extent enhance, continued U.S. strength in fundamental and applied research.[4] At this point, it is difficult to assess in a general way how these investments have affected the Japanese investors and U.S. capability to innovate. Based on the

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[2] See automobile and semiconductor equipment industry cases in Chapter 5. On autos, see "Big 3 Post Quality Gains, Japanese Still Lead," *Reuters-Yahoo News*, May 1, 1997.

[3] See Linda M. Spencer, *Unencumbered Access: Foreign Investment in the United States* (Washington, D.C.: Economic Strategy Institute, 1991), and Linda M. Spencer, *Foreign Acquisitions of U.S. High Technology Companies Database Report: October 1988-December 1993* (Washington, D.C.: Economic Strategy Institute, March 1994).

[4] National Academy of Engineering, *Foreign Participation in U.S. Research and Development* (Washington, D.C.: National Academy Press, 1996).

anecdotal information available, the task force believes that these investments have constituted a net benefit for U.S. innovation.[5]

However, the future is unclear. While Japan has announced plans to increase public support for fundamental research, in the United States both major parties are committed to balancing the budget, and debate continues over the post-Cold War rationale for government support for science and technology. In particular, some aspects of the federal government's role in science and technology development aimed at improving U.S. economic performance remains a subject of intense debate. The task force believes that this debate cannot be allowed to impair the U.S. research base.

Strength in Information Industries and Market-Driven Innovations

Another U.S. strength is its dynamic competitive market, which spurs companies to rapidly create new products and applications. The primary current example of this strength is in computers, software, and related information industry sectors. The overall level of U.S. industrial R&D spending has been relatively flat over the past decade, although investments have been growing recently. Some decry the R&D restructuring that has gone on in the industrial labs of large U.S. companies and assert that lower industry spending on R&D with medium- and longer-term payoffs will harm these companies and the United States in coming years. Others applaud the renewed focus of U.S. companies on immediate customer needs, time to market, and short-term product development performance. There is evidence that U.S. companies are once again increasing longer-term R&D spending as they are able to sustain profitability.[6] The most successful companies are increasing their own R&D investments and utilizing more basic research results generated by U.S. universities and government laboratories.[7]

In addition to trends in overall spending, there has been a shift in the industry sectors performing R&D. In recent years nonmanufacturing industries, such as software and high-technology services such as telecommunications and information systems consulting, have expanded their share of overall U.S. R&D spending. In these areas the United States is investing in the technology necessary to lead innovation in the high-growth industries of the future. However, the task force had concerns over whether investments in other fundamental areas (such as advanced materials) are adequate to maintain U.S. technology and manufacturing. It is not sufficient to judge R&D expenditures in the aggregate. More detailed analyses by industry sector and discipline will be necessary to guide policymaking.

Challenges of Continued Globalization

Although the best U.S. companies appear to be well positioned to compete in the twenty-first century on the basis of superior technology and global vision, questions can be raised over whether the United States will remain an attractive location for manufacturing and innovation and whether U.S. companies will develop capabilities to access an emerging global science and technology base. As companies, universities, and other organizations take their own approaches

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[5] One interesting example is Cymer Inc., which makes deep ultraviolet lithography lasers. Nikon and Canon bought 6 percent of Cymer in 1988. The San Diego-based company went public in 1995, sales reached $65 million in 1996, and earlier this year its market valuation reached $600 million. This is an example where Japanese investment played an important role in the commercialization of a critical U.S. technology. See Josh McHugh, "Laser Dudes," *Forbes*, February 24, 1997.

[6] Steven Payson, "R&D Growth Exceeded 1995 Expectations, but May Slow in 1996," *National Science Foundation Data Brief*, October 25, 1996.

[7] "Microsoft to Boost R&D 50%; Internet Markets Seen Key," Reuters Ltd., March 1, 1995.

to globalization, the United States will continue to find it difficult to develop a national approach to international science and technology relationships. In particular, the growing strength of laboratories, human resources, and universities outside the United States, particularly those of Japan and other Asian countries, will enable these countries to approach U.S. capabilities in all phases of research and innovation.

PRIORITIES AND POLICY OPTIONS FOR THE UNITED STATES

In light of these trends, what should be the priorities of the U.S. public and private sectors as they seek to maximize U.S. competitiveness interests in science and technology relations with Japan? This section links the broad national interest of sustaining and expanding high-wage employment in the United States with several enabling conditions related to U.S.-Japan science and technology relations, specific tasks, and supporting policies. Figure 6-1 summarizes the priorities and rationale for each.[8]

U.S. Priorities	Expand participation in Japanese and global high-technology markets	Maintain favorable environment for U.S. innovation, including public S&T investment and other elements (regulation, finance)	Pursue reciprocal, mutually advantageous relationships with Japanese counterparts
Why Important?	• Insights from customers • Organizational capabilities • Income for investment in new technologies • Prevent profit sanctuary	• Research base is a key U.S. advantage • Favorable environment builds leadership position of U.S. companies • Encourages private R&D investment in the United States	• Japan's research base is growing • Greater opportunities to pursue common interests • Japan will remain a formidable partner and competitor

FIGURE 6-1 U.S. priorities for maximizing economic benefits to U.S. citizens from science and technology relations with Japan.

[8] Although outside the scope of this study, the task force believes that these principles can and should be applied to U.S. science and technology relationships with other nations and regions, including those in Asia and Europe.

Building U.S. Capabilities to Access and Utilize Japanese Science and Technology

Over a number of years the United States has pursued a variety of efforts to build a stronger base of knowledge and expertise in Japanese science and technology. Several public-sector efforts have been undertaken within the framework of the U.S.-Japan Agreement on Cooperation in Research and Development in Science and Technology (U.S.-Japan S&T Agreement) and other agency-specific agreements.[9] Although it is difficult to directly measure the impacts on U.S. innovation capabilities and competitiveness, the task force's overall assessment is that these are well-leveraged, necessary investments that should be continued. These capabilities include (1) a group of U.S. scientists and engineers proficient in the Japanese language, with firsthand experience in Japanese R&D and manufacturing organizations and practices and (2) capabilities to collect and translate Japanese technical, business, and policy information and make this available to the U.S. private sector, preferably through electronic means. The rationale behind continued public support for these efforts is covered in Chapter 4.

The task force also considered issues related to U.S.-Japan governmental agreements and agency-to-agency cooperative programs. Although most of the important science and technology exchanges that influence economic performance and competitiveness take place in the private sector, the policy framework and official cooperation can be expected to play a more important role in the future. In particular, the task force believes that as Japan increases its fundamental research investments in coming years the United States will need a strong capability to keep track of opportunities for U.S. scientists and engineers to tap into and benefit from these efforts and to ensure they are open.

The U.S.-Japan S&T Agreement is an important component of the policy framework. The task force considered several areas in which U.S. implementation of the agreement might be improved.[10] First, as official U.S.-Japan R&D collaboration in areas such as global change, space, health, and other areas expands, the participating U.S. agencies should focus on ensuring that collaboration is effective and mutually beneficial. Increased exchange of information and perspective among U.S. agencies on various aspects of project management within the structure of the U.S.-Japan S&T Agreement would help ensure that new projects have access to an existing knowledge base and would promote greater coordination and cooperation across agencies in developing and managing cooperative programs.

Second, more focus should be placed on tracking the results of official collaboration and the overall science and technology relationship. The U.S.-Japan S&T Agreement specifies several metrics that should be compiled annually for the Joint High-Level Committee, mainly in such areas as personnel exchanges and the domestic R&D programs of each country that are open to participation on the part of the other. The task force believes that developing a simple set of metrics to be compiled each year and made available to the public would allow scientists, engineers, and policymakers to assess progress in the relationship and identify areas where additional efforts are necessary.

The metrics should include scientific and engineering personnel exchanges funded by each government (funding and number of participants for various lengths of stay), public funding of collaborative projects, participation by U.S. companies in Japan's publicly-funded R&D programs (and vice versa), and an inventory of intellectual property created by collaborative

[9] An overall positive evaluation of the agreement and suggestions for more effective implementation consistent with the task force's recommendations are contained in American Chamber of Commerce in Japan, *Making Trade Talks Work: Lessons from Recent History* (Tokyo: ACCJ, 1997), pp. 54-57.

[10] The discussion and resulting report of a workshop held in March 1996 contributed to the task force's effort. See National Research Council, *Strategies for Achieving U.S. Objectives in Science and Technology Relations with Japan* (Washington, D.C.: National Academy Press, 1996).

programs. These could be updated annually as part of the administration of the agreement. Perhaps in the future this effort could be linked with Asia Pacific Economic Cooperation and Organization for Economic Cooperation and Development efforts to develop better tools for measuring and understanding international science and technology relationships. The task force realizes that some effort and expense are involved in developing these metrics. However, much of the underlying data necessary for developing them is already collected. The main effort would be in reaching agreement on a common basis for compiling and reporting these data. The United States and Japan should take a leadership role in this regard.

Finally, the U.S. public and private sectors should extract appropriate lessons from the experience of dealing with Japan in relationships with other emerging techno-industrial powers. For example, Korea is using many features of the Japanese model of technology-driven economic development, and barriers to market participation by U.S. industry resemble those previously encountered in Japan. Over the long term, China's growing role in the world economy and technological enterprise will pose challenges and opportunities to the United States, Japan, and other developed countries. China's approach to technology acquisition for economic development is likely to feature less central coordination than the Korean and Japanese examples, but this may allow more effective integration of China's science and technology establishment into that of the United States and perhaps other countries. This emerging Sino-U.S. integration will undoubtedly give rise to synergies and mutual benefits but may prove even more challenging to the United States than the relationship with Japan has been in developing a coherent U.S. strategy for pursuing economic, security, and other interests.

Participation in Japanese and Global Markets

The task force believes that market participation is the element in the U.S.-Japan relationship that has the most impact on U.S. capabilities to generate and effectively utilize innovation to create and maintain good jobs for U.S. citizens. Participation in the Japanese market will continue to be critical, and in the future participation in Asian markets will grow relatively more important.

Demanding and Innovative Customers Spur Technology Development

The key contribution that demanding and innovative customers, or lead users, often make to the technology development efforts of individual firms and national industries is well established.[11] The importance of customers is perhaps greater for companies serving industrial markets than it is in consumer markets, where suppliers often provide key insights and innovations.

Presence in the Japanese and other advanced country markets spurs technology development at a U.S.-based company in several ways.[12] First, through the act of modifying a product to meet the needs of Japanese customers, a company can develop new product features and technologies that are applicable in other markets or even globally.

Second, if a significant part of the global market for a product consists of customers based in Japan, U.S. companies wishing to become or remain competitive must be successful in supplying Japanese firms and meeting their overall requirements for quality and performance, which could be more stringent than the requirements of firms based elsewhere. Corning's experience in

[11] Michael E. Porter, *The Competitive Advantage of Nations* (New York: Free Press, 1990); Eric A. von Hippel, "Has Your Customer Already Developed Your Next Product?" *Sloan Management Review*, Winter 1977.

[12] Box 5-1 describes a specific example.

supplying glass for flat panel displays and Rockwell's experience in supplying modem chips to Japanese customers are important examples of this benefit.

Third, participation in Japanese and other technologically sophisticated overseas markets provides a revenue base and helps establish an organizational presence. This presence facilitates the hiring of skilled local personnel, including scientists and engineers, and underwrites overhead for other activities that help establish the U.S. company as a participant in Japan-based technology and market development activities. Such a presence allows a U.S.-based company to learn about and apply technological developments and activities of Japanese suppliers, partners, and competitors faster than would be the case if there was no market presence.

Because of the rapid globalization of markets and international convergence in technological capabilities, it is imperative for firms based in the United States and elsewhere to develop, access, and utilize the world's best technology rapidly at competitive costs. In the past the external insights driving technology development were very likely to come from customers and suppliers of the same nationality. However, globally competitive firms increasingly require access to knowledge from a global customer and supply base.

Expanded Market Participation Provides Resources for Investment in Next-Generation Technology

By raising returns on technology investments, overseas sales provide resources for the development of next-generation products and processes. This is an additional critical link between overseas market participation and U.S. technology development activities. In its dispute with Fuji Film, Kodak alleges that denial of market access in Japan has caused lower levels of investment in new technology in the United States.[13]

The semiconductor manufacturing equipment (SME) industry also provides a good illustration. Leaving aside for a moment the question of what has influenced access to the Japanese market in this industry, it appears that Applied Materials, which has a much greater presence in Japan than many other U.S. SME firms, has grown faster and has access to a much larger revenue base for investment in new technologies as a result of its strong presence in Japan.

Japanese Market Barriers Have Impeded U.S. Innovation Efforts

The semiconductor industry provides a success story for expanding foreign market access in Japan. Whether improvements are due primarily to overall market trends, expanded efforts of U.S. companies, the U.S.-Japan Semiconductor Trade Agreement, or other factors, expanded market presence in recent years has increased learning from Japanese customers on the part of U.S. device makers, has increased the flow of revenue for next-generation products and processes, and has facilitated the formation of several U.S.-Japan alliances that are investing

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[13] See Thomas R. Howell and Brent L. Bartlett, *Privatizing Protection: Japanese Market Barriers in Consumer Photographic Film and Consumer Photographic Paper* (Dewey Ballantine and Eastman Kodak Company, May 1995), p. 167. In its response, Fuji Film asserts that Kodak's loss of competitive position to Fuji is partly due to insufficient and ill-conceived investments in new products and technology. See William H. Barringer, James P. Durling, Daniel L. Porter, and William B. Lindsay, *Rewriting History: Kodak's Revisionist Account of the Japanese Consumer Photographic Market* (Willkie Farr & Gallagher, Fuji Photo Film Co., Ltd., and Fuji Photo Film USA, Inc., July 1995). As this is being written, the case is being considered by the World Trade Organization. See U.S. Trade Representative, "Statement by USTR-Designate Charlene Barshefsky," February 20, 1997, and Ministry of International Trade and Industry, "Statement on the Submission of the United States to the WTO Panel on the film case," February 21, 1997.

large amounts in sophisticated manufacturing facilities and creating high-technology manufacturing employment in the United States.

Although nearly all of Japan's formal trade and investment barriers have been lifted, nontariff barriers related to Japanese policies and private business practices continue to impede access to the Japanese market in a number of key industries. The nature and impact of these policies and practices vary considerably by industry. Several specific examples of market participation barriers are described in Chapter 5, in areas such as intellectual property protection; regulation; differences in competition policy (including weaker antitrust enforcement in Japan); differences in business systems (including *keiretsu* and intercorporate links, corporate ownership, and the role mergers and acquisitions); differences in financial structures; and access to informal information networks, including industry and trade associations.

The Importance of an Open Competitive U.S. Market

The task force also believes that the largely open and highly competitive U.S. market constitutes a major source of advantage for U.S.-based companies in a range of industries relative to Japan and most European countries.

In the automobile industry it was Japanese competition and direct investment that forced the Big Three automakers and major suppliers to improve their manufacturing and product development performance. In the most rapidly developing, leading-edge sectors, such as information industries and biotechnology, Japanese and other foreign companies have established an R&D presence in the United States to stay abreast of developments.[14] The dynamic U.S. market in information technologies is a major factor in the ability of U.S.-based companies to establish de facto standards, which frequently lead to strong advantages in the marketplace.

U.S. Trade Policy

There are several possible approaches the United States might take to encourage greater openness in the Japanese and other overseas markets.[15] The first approach would be an aggressive trade policy featuring more vigorous self initiated Section 301 cases, setting targeted market shares and imposing sanctions when they are not reached. A second alternative would be an assertive trade policy that tries to break down general structural barriers, such as intellectual property protection, and address specific market access issues in Japan, with an expanding focus on Asia (similar to current policies and trends). A third approach would be to reduce emphasis on bilateral trade negotiations and focus on multilateral and regional liberalization.

Task force members hold a range of views on whether past U.S. bilateral trade approaches toward Japan have been effective, and on the relative emphasis that the United States should put on bilateral, regional, and multilateral initiatives in the future. The task force does agree that effective implementation of the Uruguay Round, including the stronger dispute settlement powers of the World Trade Organization (WTO), would significantly advance U.S. interests. There are different views on the progress made thus far and on future prospects. Several

[14] See the Richard Florida-Alan Tonelson debate in *Issues in Science and Technology*, Spring 1995 and Summer 1995, on advantages and disadvantages of relative U.S. openness to foreign-owned technological activities.

[15] The policy issues related to international trade and national technology capabilities are covered by the Hamburg Institute for Economic Research, Kiel Institute for World Economics, and National Research Council in *Conflict and Cooperation in National Competition for High-Technology Industries* (Washington, D.C.: National Academy Press, 1996). This international project takes up issues of trade and technology in a broader context.

members are encouraged by the WTO's ruling against Japan in the *shochu* case, where a significantly lower tax rate on a native Japanese liquor relative to internationally traded varieties was judged to be trade distorting.[16] They would put primary emphasis on strengthening the WTO and would deemphasize bilateral trade approaches.

Other task force members believe that it is too early to tell whether WTO will become effective enough to protect U.S. interests within a reasonable amount of time. They would prefer that the United States maintain a focus on bilateral trade issues and a willingness to use unilateral trade sanctions against trade practices that violate U.S. laws. According to this formulation, the ability of the United States to utilize bilateral and unilateral approaches has contributed to progress on the multilateral agenda, both regionally (in the Asia Pacific Economic Cooperation forum) and more broadly. If the United States were to give up these bargaining chips, some countries might have less incentive to make full efforts toward adherence to WTO and future multilateral liberalization.

In addition to agreeing that a strong effective WTO is in U.S. interests, task force members agree that future priority in multilateral negotiations should be on areas where particular market access barriers in Japan have arisen: competition policy and direct investment. Several specific examples are discussed in Chapter 5. For example, stronger multilateral rules on competition policy could help address Japanese private sector practices such as tight links between distributors and manufacturers that have hindered the ability of new entrants to access Japanese distribution systems. Private-sector conditions and practices are also largely responsible for the continued difficulties that foreign and other new entrants have in accessing the Japanese market through direct investment.[17] In a multilateral context, progress in these areas will help ensure better returns to U.S. innovators from today's emerging markets than what was possible during Japan's high-speed growth period.

The task force also believes that Japan and the United States will share common interests on an increasing number of global trade issues. In promoting adherence to multilateral rules by developing countries and working to develop common approaches to emerging issues such as trade and the environment, the United States and Japan can contribute to further positive development of the world trading system. This is of major importance to both countries.

Intellectual Property

Intellectual property protection and its relationship with market participation deserves special focus and attention. Improving intellectual property protection for U.S. inventions will be a key determinant of whether the United States gains adequate returns on its investments in innovation. International intellectual property policies are formed through several fora. Harmonization of national intellectual property laws is pursued through the World Intellectual Property Organization. Trade-related intellectual property provisions were included in the Uruguay Round, where developing countries agreed to implement intellectual property protection on a predetermined timetable. Regional trade agreements such as the North American Free Trade Agreement and the Asia Pacific Economic Cooperation forum have established or are discussing intellectual property provisions. Agreements also have been concluded with individual countries, including Japan.

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[16] "Bei, Ka no dekata futomei" (U.S., Canadian Attitudes Unclear), *Nihon Keizai Shimbun,* December 17, 1996, p. 5.

[17] The United States and Japan also signed a bilateral agreement on investment in 1995.

Pursuing U.S. interests in this area will be complex and difficult but nonetheless very important.[18] U.S. innovators experience greater difficulty in gaining intellectual property protection in Japan than in the United States and Europe.[19] Particularly for small high-technology companies, market entry can be difficult or impossible without enforceable intellectual property protection.

A few lessons from the Japan experience are clear. To begin with, the situation has improved over recent years, for several reasons. Perhaps most importantly, efforts to strengthen U.S. intellectual property protection over the past several decades, including unification of appellate jurisdiction under the U.S. Court of Appeals for the Federal Circuit, have given U.S. innovators a stronger hand in dealing with Japanese counterparts. Trade provisions that allow for blocking importation of products utilizing components or processes that infringe on a U.S. patent make it more likely that Japanese companies will recognize the rights of U.S. inventors, since most high-technology products are developed for a global market. In 1994 the United States concluded two intellectual property agreements with Japan aimed at ameliorating several of the most difficult problems U.S. inventors face in the Japanese system.[20]

Another lesson of U.S. firms' experience with Japan regarding intellectual property protection is that implementation and enforcement are at least as important as written policies. This has been the case with China as well, where U.S. intellectual property rights complaints center on China's lax enforcement of its own laws.

U.S. policies to improve global intellectual property protection for U.S. inventions will probably continue to be multifaceted in coming years, taking the form of multilateral, regional, and bilateral agreements and steps to monitor and enforce agreements and patent harmonization. In addition to steps already being taken, the task force has developed an additional initiative. This comes from the observation that gaining intellectual property protection in Japan has been particularly difficult for some fundamental inventions, such as the integrated circuit patent of Texas Instruments. Since these sorts of inventions have a relatively high impact on the U.S. economy, taking steps to ensure global protection for key innovations would be worth exploring. The task force suggests that the U.S. Trade Representative and the U.S. Patent and Trademark Office jointly set up a system to monitor patent applications for key innovations in Japan and perhaps other large markets where U.S. innovators have experienced difficulties.[21] U.S. inventors could request that the progress of their Japanese applications and postgrant enforcement be monitored. If the invention does not achieve timely and effective protection, government-to-government talks could be initiated, with the possibility of WTO or other action if satisfactory results are not realized.

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[18] Benedicte Callan, "Pirates on the High Seas: Why We Care About Global Intellectual Property Rights and What We Can Do About Them," Council on Foreign Relations, 1997.

[19] U.S. General Accounting Office, *U.S. Companies' Patent Experiences in Japan* (Washington, D.C.: U.S. Government Printing Office, 1993).

[20] One agreement allowed for Japanese patents to be filed in English and changed the U.S. patent term. Another agreement resulted in changes to Japan's system of opposing patents. Office of the U.S. Trade Representative, *President's 1994 Report on the Trade Agreements Program*, 1995.

[21] One important question is how "key innovations" would be defined and identified under such a program. The task force would rely on self selection to the extent possible. In principle, any company or individual inventor that takes the time and trouble to seek intellectual property protection in a number of markets, is concerned that effective protection may be blocked or delayed, and is willing to work with the U.S. government to seek remedies should be eligible. If the number of companies or inventors seeking a place on the list gets unmanageable, selection criteria would need to be rethought. The task force does not believe that this is likely.

Lessons and Imperatives for U.S. Companies

The Japan experience provides a number of lessons for U.S. companies seeking to participate in markets and build technological capabilities worldwide, particularly in Asia. Attention to the following elements may help ensure that U.S. companies establish strong positions in Asian markets and manage the risk of creating potential competitors:

1. U.S. innovators should protect intellectual property carefully, particularly in the United States. Although protecting intellectual property in Japan and other countries has been and is likely to remain difficult, U.S. companies such as Texas Instruments and IBM have found that the effort is well worth it. In addition, because potential competitors are likely to seek access to U.S. markets, effective protection of intellectual property rights in the United States is a critical element in ensuring that products based on infringed technologies do not pose a threat in the U.S. market.

2. Where possible, build market participation "tollgates" into technology transfer deals. Although transfer of know-how may be a requirement for entering some rapidly growing Asian markets, care should be taken to ensure that partnerships build a long-term position in the market. For example, Motorola's deal with Toshiba reportedly made given levels of technology transfer to Toshiba contingent on Motorola reaching specified sales levels in Japan.[22]

3. Cultivate host country allies. In a historical example, Mitsubishi Heavy Industries (MHI) played a key role in pressuring the Japanese government and soft drink companies such as Kirin to allow Coca-Cola's entry into Japan in the 1950s because MHI stood to benefit as a licensed manufacturer of Coca-Cola bottling equipment.[23]

Maintaining U.S. Capabilities in Science, Technology, and Innovation

Another key priority for the United States will be to maintain capabilities in science, technology and, innovation, including manufacturing. A favorable environment for innovation has a number of elements, including a dynamic market (as discussed above), supportive policies in areas such as capital formation and regulation, as well as public- and private-sector investments in science and technology.[24]

Federal Role in Science and Technology with Commercial Applications

Although the task force recognizes that all the elements of a favorable innovation climate are important, issues related to the federal role in technology research and development with commercial applications were the focus of particular task force deliberation because U.S. policy changes in this area have partly been prompted by the competitiveness challenge that emerged in Japan. Japan is now making significant changes in its own government approach to supporting science and technology. Several lessons can be drawn from this experience.

The United States has undertaken a number of new initiatives and policy changes since the early 1980s to improve industry-university-government collaboration in civilian technologies with the aim of improving the return on U.S. R&D investments. These include the Bayh-Dole

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[22] National Research Council, *U.S.-Japan Strategic Alliances in the Semiconductor Industry: Technology Transfer, Competition and Public Policy* (Washington, D.C.: National Academy Press, 1992), pp. 94-95.

[23] Mark Mason, *American Multinationals in Japan* (Cambridge, Mass.: Harvard University Press, 1992), p. 170.

[24] The interconnected elements in a strong environment for innovation are covered by the Center for Strategic and International Studies (CSIS) in *Global Innovation, National Competitiveness* (Washington, D.C.: CSIS, 1996).

Act (1980), the National Cooperative Research Act (1984), the Engineering Research Centers program of the National Science Foundation (1985), the Federal Technology Transfer Act (1986), SEMATECH (1987), the Advanced Technology Program of the U.S. Department of Commerce (1991), the High Performance Computing and Communications Initiative (1991), and the Partnership for a New Generation of Vehicles (PNGV) (1993). The task force believes that U.S. innovation is stronger as a result of these efforts. The evidence confirms that the federal government should play a strong role in investing in long-term, high-risk research that provides an R&D platform for next generation products, particularly where agency or broader national interests are directly engaged. For example, Ford credited PNGV-derived technologies in its recent announcement of a prototype ultra high mileage, environmentally friendly vehicle.[25] In many cases the social returns to such R&D programs, in terms of improved U.S. economic performance and improved ability to address other national imperatives, will justify public investment in R&D that would not clear the hurdle rate for expected returns for a private company.

Although there are differences of perspective on the task force regarding the appropriate size and emphasis of particular programs and activities, the members agree that government, industry, and universities must continue to work together to improve the effectiveness of existing technology partnerships and to develop new approaches. Japan and a number of emerging techno-industrial powers are seeking to improve their capabilities through higher investments in R&D and more effective industry-government-university links. Japan has traditionally focused relatively more public effort than has the United States on science and technology investments explicitly aimed at enhancing the technology levels and capabilities of firms operating in commercial markets. Although more recent Japanese efforts have had mixed results, there are several examples of success, and a number of experts have pointed out that the value of these initiatives goes beyond sales generated directly by the research results of R&D consortia.[26]

In light of these experiences it would appear that a pragmatic nonideological approach should be utilized to improve U.S. capabilities in the future. It will be necessary to monitor and evaluate programs and policies with the long-term view of fostering effective innovation.

Foreign Participation

Another issue considered by the task force is foreign participation in government-funded R&D, particularly in programs targeted at commercial or potentially commercial areas. Several recent reports have addressed this issue.[27] Currently, the United States and other countries have a variety of policies for regulating foreign access to national technology programs. There are no multilateral disciplines, except for R&D subsidies that are trade distorting above a significant threshold.[28] A number of U.S. programs contain nondiscriminatory performance requirements

[25] "Ford Building Breakthrough Prototype Vehicle," Ford Motor Co. press release, March 17, 1997.

[26] See the discussion of superconductivity and engineering ceramics examples by Gerald J. Hane in "Research and Development Consortia and Innovation in Japan: Cases in Superconductivity and Engineering Ceramics," doctoral dissertation, Harvard University, May 1992.

[27] Hamburg Institute for Economic Research, Kiel Institute for World Economics, and National Research Council, op. cit., and National Academy of Engineering, *Foreign Participation in U.S. Research and Development: Asset or Liability?* (Washington, D.C.: National Academy Press, 1996).

[28] The basic approaches to regulating access to national technology programs are (1) reciprocity, or allowing access by foreign companies if their home countries provide access to equivalent programs; (2) national treatment, or treating foreign companies and U.S. companies equally; and (3) harmonization—while adopting either of the above, work for international harmonization of policies in these areas. For a more detailed description of aspects of these approaches, see U.S. Congress, Office of Technology Assessment, *Multinationals and the National Interest: Playing by Different Rules* (Washington, D.C.: U.S. Government Printing Office, 1993), pp. 17-19.

mandating that resulting products be substantially manufactured in the United States. In addition, several programs include reciprocity provisions that require the home governments of foreign-based participants to grant U.S.-based companies access to similar programs.

The task force agrees that in the future tapping the capabilities of foreign-based companies will sometimes be required to meet the national goals pursued through government R&D programs. However, there are differences of perspective over how the issue should be addressed by the United States in the short term.

Several members point out that there is no evidence that reciprocity requirements advance national interests or actually lead to greater reciprocity. Barring access to otherwise qualified foreign-based companies may deprive a project of important capabilities. In addition, reciprocity requirements go against long-standing U.S. commitments to the principle of national treatment. According to this perspective, the United States should drop reciprocity requirements where they exist today and not include them in future programs. Reciprocal access to foreign government programs should be pursued through the formulation of multilateral rules. The underlying ability of U.S.-based firms to participate effectively in foreign R&D programs should also be pursued through multilateral rules covering competition policy and direct investment, as outlined above. Finally, some members would retain nondiscriminatory performance requirements focused on ensuring that corporate participants retain full-spectrum capabilities in the United States, including R&D and manufacturing.

Other task force members believe that in the absence of multilateral rules reciprocity is a perfectly reasonable condition to insist on where publicly-funded research might result in benefits to companies based outside the United States and to foreign citizens. This is particularly true in the case of Japan. Japanese companies and citizens already enjoy broad access to U.S. R&D conducted at universities and national laboratories. Survey and anecdotal reports indicate that Japanese companies make strategic and targeted use of this access.[29] Because of the relatively greater difficulty experienced by U.S. industry in participating in the Japanese market, as described above, U.S.-based companies generally have less ability to participate in Japanese publicly funded R&D. In addition, Japanese and U.S. approaches to formulating commercially oriented technology programs are quite different. While the United States tends to rely on transparent competitive procedures for developing programs, Japan often develops initiatives through informal consultations some time before projects are funded.[30] In recent years, foreign companies have sometimes been invited to participate in Japanese programs based on their capabilities. Some task force members believe that at least in Japan's case reciprocity requirements may be warranted for some programs until opportunities to access Japanese programs can be ensured.

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[29] National Academy of Engineering, op. cit., and National Research Council, *Foreign Company Access to U.S. Government Laboratories: Report of a Workshop* (Washington, D.C.: National Academy Press, 1994).

[30] National Academy of Engineering, op. cit.

7
Conclusions and Policy Recommendations[1]

MAJOR FINDINGS

Science and Technology Interactions Have Had a Considerable Impact on Economic Performance

The acquisition, effective adaptation and improvement of technologies from abroad, mainly from the United States, have served as a basis for Japan's rapid economic growth and international competitiveness in a wide variety of manufacturing industries. For the United States the economic benefits of science and technology interaction with Japan have been much lower in relative and absolute terms. There are indications of growing benefits in recent years, particularly in industries where opportunities to participate in the Japanese market have improved, and industries where Japanese investment in the United States has contributed to maintaining U.S. capabilities.

The U.S.-Japan Science and Technology Relationship Is Changing

In recent years a number of major changes have occurred in the U.S.-Japan science and technology relationship, most of them positive from a U.S. perspective. The strengths of the U.S. innovation and market systems have reasserted themselves, particularly, but not exclusively, in information-related industries. Information about Japanese science and technology is much more widely available, and a growing group of U.S. scientists and engineers are capable in the Japanese language and experienced in the Japanese research and innovation environment. A wide range of U.S. manufacturing companies have developed more effective approaches to innovation, manufacturing, and marketing, in some cases adapting aspects of Japanese practices. At the same time, Japanese government and industry strategies to further strengthen Japan's leading role in global high-technology development and manufacturing have recently met with diminishing returns. Approaches to industrial development based on technology acquisition and improvement have become less effective due to the higher risks and uncertainties faced by Japanese companies as they have reached the technological frontier. Japanese firms also have faced challenges from new technological and industrial competitors in markets where they had established strong positions, such as semiconductor memories.

[1] The purpose of this chapter is to present the conclusions and recommendations in a concise way. Further discussion of the reasoning behind the task force's conclusions and recommendations, including consideration of alternative approaches considered by the task force, is provided in Chapter 6. The Executive Summary presents highlights of the conclusions and recommendations within the context of the entire study.

But Important Asymmetries Continue to Exist

Although the structural asymmetries in the U.S.-Japan science and technology relationship appear to have a less harmful impact on particular U.S. companies and industries now than has been the case in the past, wide imbalances still exist. Opportunities for U.S. companies to fully participate in the Japanese market are still constrained in a number of high-technology industries. Statistics on personnel exchanges, technology licensing between unaffiliated companies, and other aspects of the relationship reflect continued asymmetries. Therefore, a clear focus by policymakers and corporate managers on addressing these asymmetries will continue to be important.

Japan Will Continue to Be a Major Partner and Competitor

Japan-based companies, and most likely Japan as a location for research, innovation, and manufacturing, will remain formidable. Despite recent setbacks in competitiveness and technology development, the task force believes that Japanese companies will remain among the leading international competitors and collaborators for U.S. industry in a range of high-technology manufacturing and service industries. The task force also believes that the current effort by the Japanese government to increase support for fundamental research will lead to noticeable gains in the depth, breadth, and quality of Japanese research over the next decade.

U.S. Government Policies Should Be Oriented Toward the Long Term and Should Incorporate Industry Perspectives

Future relations with Japan in science and technology can advance U.S. economic interests and involve greater mutual benefit than has been the case in the past, but formulating appropriate U.S. strategies requires a long-term perspective and consistent policy approach. Policymaking should include participation by U.S. industry. U.S. government and industry should aim over the long term to build domestic capabilities and international relationships in science, technology, and innovation that sustain and enhance wealth creation and high-wage employment in the United States. In particular, U.S. government and industry must continue efforts to build a more reciprocal U.S.-Japan science and technology relationship.

Key Challenges Are Emerging in Asia

The key future challenges facing the United States and Japan in ensuring that international science and technology relationships enhance domestic economic performance lie in Asia. Although addressing issues related to Asian scientific and technological ascendancy is beyond the scope of this study, the task force believes that its priorities and recommendations for the U.S.-Japan relationship are broadly applicable to science and technology relations with other countries, including the countries of Asia.

PRIORITIES FOR THE UNITED STATES AND POLICY RECOMMENDATIONS

Continue Public Support for National Capabilities Needed to Access and Utilize Japanese Science and Technology

The relatively modest public investments in Japanese language training and Japanese research opportunities for U.S. scientists and engineers, and in efforts to collect and disseminate Japanese scientific and technological information, are valuable and should be maintained.

Recommendations

1. Stable, long-term U.S. government investment in training a group of Japan-capable scientists and engineers should be maintained, particularly where limited U.S. investments leverage significant amounts of Japanese funding.

2. The U.S. government should maintain support for efforts to obtain, translate, and disseminate Japanese scientific, technical, business, and policy information.

3. The U.S. government should continue to press Japanese government and companies to make certain categories of information that affect market participation and technology relationships, particularly laws, regulations, administrative guidance, and other policy-relevant documents, available to the public, preferably electronically.

4. U.S. industry and industry associations should redouble their efforts to expand access to the Japanese market and Japanese technology and seek a greater role in Japanese and U.S. policy debates.

Renew Efforts to Engage Japan in Mutually Equitable Science and Technology Relationships

The task force believes that Japan will follow through on its stated goal of sharply increasing public spending on science and technology over the next several years. As the Japanese science and technology budget is rising rapidly and growth in the U.S. budget will be constrained at best, now is precisely the time that the U.S. private and public sectors should renew their efforts to engage Japan in cooperation that delivers equitable benefits.

Recommendations

5. The U.S. government should actively use the U.S.-Japan Science and Technology Agreement to advance U.S. interests by encouraging effective program management, developing metrics to track progress in the overall relationship, and ensuring that Japan's new publicly-funded research efforts are open.

6. The United States should encourage expanded Japanese contributions in science, technology, and other cooperation that creates global benefits.

7. U.S. companies and the U.S. government should utilize lessons from dealing with Japan in their dealings with emerging techno-industrial powers.

Increase the Economic Benefits from U.S. Science and Technology Through Enhanced Industry-University-Government Cooperation

This is no time to rest on our laurels. Japan and other countries around the world will continue to improve their own approaches to innovation. The United States must do the same. Although some aspects of federal support for civilian R&D are controversial, there is clearly room for better approaches to cooperation between industry, university, and government sectors in research, development, and commercialization.

Recommendation

8. U.S. industry, universities, and government should continue to increase investments in science and technology and develop new collaborative mechanisms that increase the economic returns on this investment. Partnerships focused on important commercial technologies linked with agency or broader national needs should be a particular priority. Resolving the issue of foreign participation in such programs, and participation by U.S.-based companies in foreign government programs, is a pressing task for the future.

Expand Market Opportunities for U.S. Science and Technology-Based Products in Japan and Globally

As this report documents, Japanese market access barriers have played a major role in differential economic benefits that Japan and the United States have derived from science and technology cooperation. Expanding opportunities for sales in foreign markets of U.S. science and technology-based products is increasingly essential to maintaining U.S. capabilities to generate and utilize innovation. Although there is a range of views on the task force regarding appropriate trade policy, there is agreement on several U.S. priorities for the future.

Recommendations

9. Effective implementation of the Uruguay Round will advance U.S. interests considerably. In future multilateral negotiations the United States should focus on areas where barriers to participation in the Japanese market continue to arise: direct investment and competition policy.

10. The U.S. Trade Representative's Office, U.S. Patent and Trademark Office, and U.S. industry should develop a process to identify patent applications by U.S. citizens in Japan and perhaps other countries that covers major scientific and technological advances to ensure that these critical patents receive timely and effective protection.

11. The United States should explore areas for cooperation and coordination in trade policy and in other areas with Japan and other countries to promote more open access to markets and economies in developing countries. As more developing countries recognize the value of foreign direct investment in raising their technology levels, the United States and Japan can have a greater impact when working together to encourage adherence to multilateral rules, and discourage national approaches that feature focused technology transfer as a condition for market participation. The United States and Japan should also work to develop common approaches to emerging issues on the multilateral agenda, such as trade and the environment.

Appendix A
Workshops Organized by the Committee on Japan as Input for the Study on Maximizing U.S. Interests

FOREIGN COMPANY ACCESS TO U.S. NATIONAL LABORATORIES
December 16, 1993

Agenda
9:00 am Chairman's Opening Remarks (Erich Bloch, Council on Competitiveness)

Discussion Topics:
- Foreign Company Access to U.S. National Laboratories—Current Status and Trends
- Benefits and Risks of Interaction
- U.S. Industry Access to Japanese Government-Sponsored R&D
- Policies Toward Access
- Developing a Proactive U.S. Approach

4:00 pm Adjourn

Presenters and Discussants
Ray Ahearn, Office of the U.S. Trade Representative
Jim Anderson, Ford Motor Co.
Bill Appleton, Oak Ridge National Laboratory
Mark Bohannon, U.S. Department of Commerce
John Boright, U.S. Department of State
Philip Chen, National Institutes of Health
Mary Beth Davis, U.S. Department of Energy
John DeMember, Digital Equipment Corp.
Gerry Dinneen, National Academy of Engineering
David Goldston, House Committee on Science, Space and Technology
Michael Graham, Pacific Northwest Laboratory
Jessie Harris, U.S. Department of Energy
Colin Helmer, U.S. Department of State
Joseph Hezir, OP Group
Russell Jamison, Smith and Nephew Richards
Elton Kaufmann, Argonne National Laboratory
Dick Kegg, Cincinnati Milacron
Bob Kneller, National Institutes of Health

Norman Kreisman, U.S. Department of Energy
Burgess Laird, Los Alamos National Laboratory
Elliot Maxwell, National Institute of Standards and Technology
Duncan Moore, Office of Senator John D. Rockefeller IV
Proctor Reid, National Academy of Engineering
Jack Simon, General Motors
George Sinnott, National Institute of Standards and Technology
Pace VanDeVender, Sandia National Laboratory
Mauro Walker, Motorola Inc.
Deborah Wince-Smith, Council on Competitiveness
Stanley Zehr, Rockwell International

U.S. INDUSTRY NEEDS AND ACCESS TO JAPANESE SCIENTIFIC AND TECHNICAL INFORMATION
June 15, 1994

Agenda

8:45 am	Chairman's Opening Remarks (Jim Martin, Rockwell Science Center)
9:00	U.S. Industry Needs and Corporate Approaches John Oblak and Bryan Moser, United Technologies Corp. Terrence Heng, Motorola Inc.
10:30	U.S. Government Programs Phyllis Genther Yoshida, U.S. Department of Commerce Ritsuko Gray, FBIS Glenn Hoetker, Dewey Ballantine
12:00 pm	Learning from Japanese Approaches John Quinn, Quinn International
1:00	Consortia, University, and Other Private Sector Activities Howard Curtis, MCC Mindy Kotler, Japan Information Access Project Hillary Handwerger, NCMS Richard Schlichting, University of Arizona
2:45	Implementation Issues: Utilizing Information Technology to Meet U.S. Industry Needs Alan Marwick, IBM Corp.
3:30	Conclusions and Policy Issues
4:30	Adjourn

Presenters and Discussants
Claude Cavender, Japan Information Access Project
Maurice Cloutier, Foreign Broadcast Information Service
Howard Curtis, MCC
Eric Gangloff, Japan-United States Friendship Commission
Ritsuko Gray, Foreign Broadcast Information Service
Hillary Handwerger, National Center for Manufacturing Sciences
Colin Helmer, U.S. Department of State
Terrence Heng, Motorola Inc.
James Hiney, Noise Cancellation Technologies
Glenn Hoetker, Dewey Ballantine
John Hopper, U.S. Department of Defense
David Icikson, U.S. Department of Energy
Mindy Kotler, Japan Information Access Project
Norman Kreisman, U.S. Department of Energy
Susan Lusk, Japan Information Access Project
Alan Marwick, IBM Corp.
Duncan Moore, Office of Senator John D. Rockefeller IV
Bryan Moser, United Technologies Corp.
John Oblak, United Technologies Corp.
Patti O'Neill-Brown, U.S. Department of Commerce
John Quinn, Quinn International
Richard Schlichting, University of Arizona
Linda Staheli, Office of Science and Technology Policy
Pat Tsuchitani, National Science Foundation
Phyllis Genther Yoshida, U.S. Department of Commerce

DEVELOPING HUMAN RESOURCES TO COMPETE AND COOPERATE WITH JAPAN IN SCIENCE AND TECHNOLOGY

August 24, 1994

Agenda

9:00 am Chairman's Opening Remarks (Jim Martin, Rockwell Science Center)

9:10 Researcher Experiences in Japan and Their Value in the U.S. Market
Anders Solem, General Electric
Michael Barnett, Hydromantis Co.
Andy Howard, Hewlett-Packard
Jay Martin, University of Wisconsin, Madison
Janice Cassidy, National Science Foundation

10:10 Industry Perspectives on the Value of Japan Expertise

Thomas Keogh, Westinghouse-Mitsubishi Electric Co. Exchange Engineer Program

Don Shaw, Establishing a Research Laboratory in Japan, Texas Instruments' Tsukuba Research Laboratory

Webster Howard, Managing an Industrial Alliance, the IBM-Toshiba Flat Panel Displays Joint Development Project

Yoshio Nishi, American and Japanese Perspectives

12:15 pm Program Perspectives—New Efforts to Develop Human Resources

2:00 Roundtable Discussion to Develop Conclusions and Policy Options and Alternatives

4:30 Adjourn

Presenters and Discussants

Mark Aguiar, U.S. Department of State
Michael W. Barnett, Hydromantis, Inc.
Keith Brown, University of Pittsburgh
Robert A. Burmeister, Stanford University
Janice Cassidy, National Science Foundation
Thomas Chapman, University of Wisconsin, Madison
William Cummings, State University of New York, Buffalo
Richard Dasher, Stanford University
Barry Dayton, 3M Corp.
Patricia Gercik, Massachusetts Institute of Technology
Colin Helmer, U.S. Department of State
Andy Howard, Hewlett-Packard Co.
Webster Howard, AT&T Bell Laboratories
Thomas J. Keogh, Westinghouse (retired)
Robert Kneller, National Institutes of Health
Norman Kreisman, U.S. Department of Energy
Wally Lopez, University of New Mexico
Jay Martin, University of Wisconsin, Madison
J.J. Neale, Eastman Kodak Company
Yoshio Nishi, Hewlett-Packard Co.
Patti O'Neill-Brown, U.S. Department of Commerce
John Purcell, IBM Corp.
Don W. Shaw, Texas Instruments, Inc.
John Shook, University of Michigan
Anders E. Solem, General Electric Company
Linda Staheli, Office of Science and Technology Policy
John Thome, Motorola Inc.
Patricia Tsuchitani, National Science Foundation

Koto White, Air Force Office of Scientific Research
Phyllis Genther Yoshida, U.S. Department of Commerce

JAPANESE ADVANCED MANUFACTURING TECHNOLOGY: U.S. INDUSTRY NEEDS AND ACCESS
September 8, 1994

Agenda

9:00 am	Chairman's Opening Remarks (Jim Solberg, Purdue University)
9:15	Participant Perspectives
10:30	Promising Areas for U.S.-Japan Cooperation in Advanced Manufacturing
1:30 pm	Possible Mechanisms for Cooperation
3:00	Conclusions
3:45	Chairman's Summary
4:00	Adjourn

Presenters and Discussants
Joe Bordogna, National Science Foundation
Deborah Carr, Coalition for Intelligent Manufacturing Systems
Janice Cassidy, National Science Foundation
Gerry Dinneen, National Academy of Engineering
Hal Edmondson, Hewlett-Packard (retired)
Ken Flamm, U.S. Department of Defense
Ken Gabriel, Advanced Research Projects Agency
Colin Helmer, U.S. Department of State
Wayne Hofer, U.S. Department of Energy
John Hopper, U.S. Department of Defense
Rick Jackson, National Institute of Standards and Technology
Lee Kapor, GE Aircraft Engines (retired)
Bruce Kramer, National Science Foundation
Rakesh Mahajan, Deneb Robotics
Ed Miller, National Center for Manufacturing Sciences
Mark Mitchell, Corning Inc.
Patti O'Neill-Brown, U.S. Department of Commerce
Pat Tsuchitani, National Science Foundation
Mike Wozny, National Institute of Standards and Technology
Bob Verbal, Ford Motor Co.

Andy Wan, U.S. Department of Commerce
Larry Weber, National Science Foundation
Phyllis Genther Yoshida, U.S. Department of Commerce

JAPAN: THE EMERGING COMPETITIVE PARADIGMS
January 11-13, 1995

Agenda
Day One
6:30 pm Comments by Steven Vogel, University of California, Irvine

Day Two
8:15 am Chairman's Opening Remarks (Jim Martin, Rockwell Science Center)

8:30 Semiconductor Manufacturing Equipment
Robert Leachman, University of California, Berkeley
Richard Aurelio, Varian Associates
Papken Der Torossian, Silicon Valley Group

10:30 Biotechnology, Pharmaceuticals, and Health Care
Aki Yoshikawa, Stanford University
Carole Cooper Martin, Pacific Bio-Link Consulting

1:30 pm Advanced Materials
Bill Flock, Coors Electronic Packaging

3:30 Autos
Mike Smitka, Washington and Lee University
Larry Hagood, Johnson Controls
Gerry Conover, Ford Motor Co.

5:30 Adjourn

Day Three
8:30 am Information Industries
Michael Borrus, University of California, Berkeley

10:30 Over Arching Themes and Key Questions

Noon Adjourn

Presenters and Discussants
Richard Aurelio, Varian Associates
Erich Bloch, Council on Competitiveness

Michael Borrus, University of California, Berkeley
Benedicte Callan, University of California, Berkeley
Gerry Conover, Ford Motor Co.
Carole Cooper Martin, Pacific Bio-Link Consulting
Papken Der Torossian, Silicon Valley Group
Bill Flock, Coors Electronic Packaging
Larry Hagood, Johnson Controls
Norman Kreisman, U.S. Department of Energy
Robert Leachman, University of California, Berkeley
Mike Smitka, Washington and Lee University
Pat Tsuchitani, National Science Foundation
Steven Vogel, University of California, Irvine
Aki Yoshikawa, Stanford University

Appendix B
Committee on Japan Publications

Strategies for Achieving U.S. Objectives in Science and Technology Relations with Japan: Report of a Workshop, 1996

Maximizing U.S. Interests in Science and Technology Relations with Japan: Report of the Defense Task Force, 1995

High-Stakes Aviation: U.S.-Japan Technology Linkages in Transport Aircraft, 1994

Corporate Approaches to Protecting Intellectual Property--Implications for U.S.-Japan High Technology Competition: Report of a Workshop, 1994

Japan's Growing Technological Capability: Implications for the U.S. Economy, 1992

U.S.-Japan Strategic Alliances in the Semiconductor Industry: Technology Transfer, Competition, and Public Policy, 1992

U.S.-Japan Technology Linkages in Biotechnology: Challenges for the 1990s, 1992

Japanese Investment and Technology Transfer--An Exploration of Its Impact: Report of a Workshop, 1992

Intellectual Property Rights and U.S.-Japan Competition in Biotechnology: Report of a Workshop, 1991

R&D Consortia and U.S.-Japan Collaboration: Report of a Workshop, 1991

Expanding Access to Precompetitive Research in the United States and Japan: Biotechnology and Optoelectronics, 1990

Japanese to English Machine Translation: Report of a Symposium, 1990

Science, Technology and the Future of U.S.-Japan Relations, 1990

Approaches to Robotics in the United States and Japan: Report of a Bilateral Exchange, 1990

Learning the R&D System: Industrial R&D in the United States and Japan, 1990

Learning the R&D System: National Laboratories and Other Non-academic, Non-industrial Organizations in Japan and the United States, 1990

Learning the R&D System: University Research in Japan and the United States, 1989

The Working Environment for Research in U.S. and Japanese Universities: Contrasts and Commonalities, 1989